EECS E6893 Big Data Analytics
HW4: Generative AI – Part I

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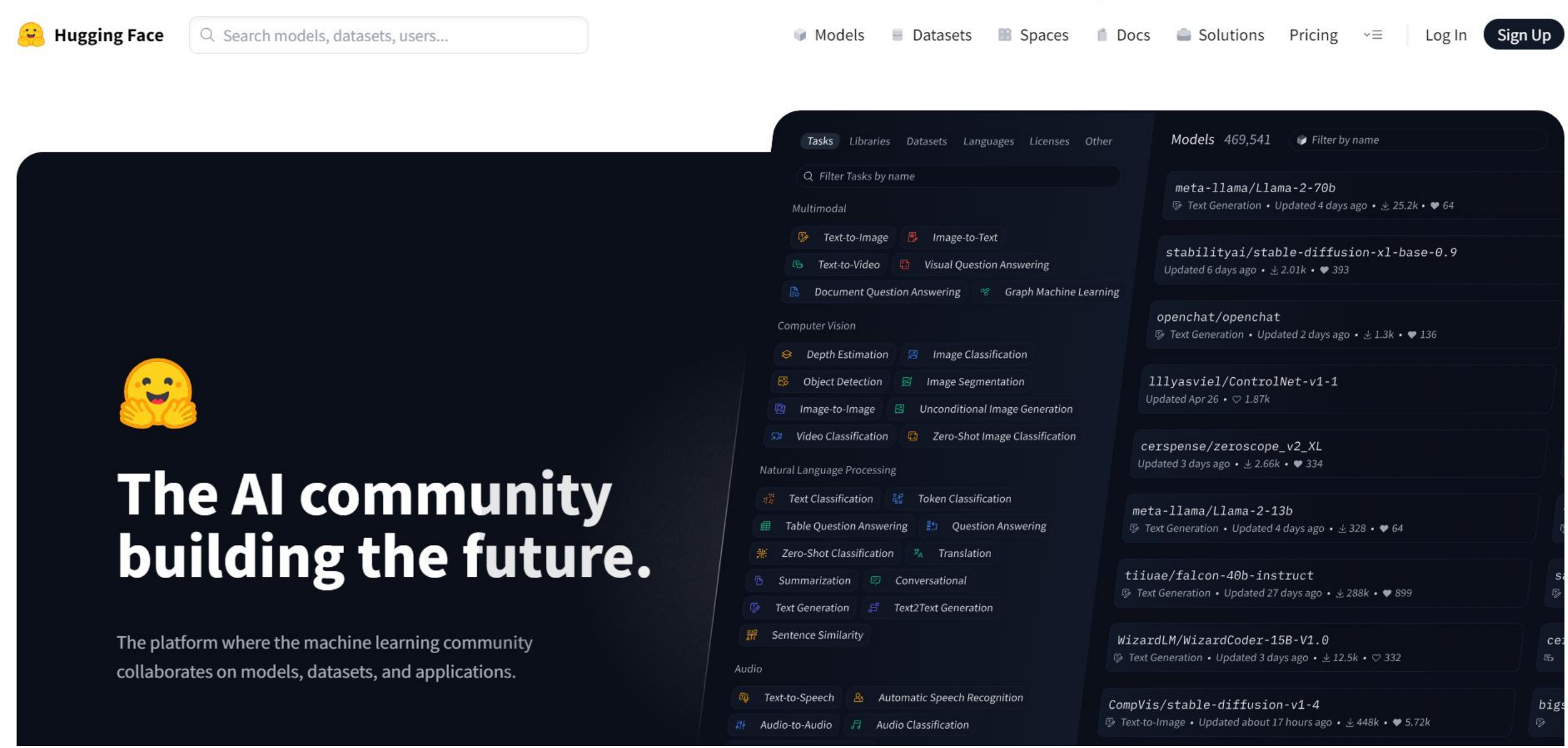
Agenda

- Hugging Face
- Llama 2
- Fine-tuning
- Build Chatbot using LangChain


Hugging Face
Search models, datasets, users...
Models
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The AI community building the future.
The platform where the machine learning community collaborates on models, datasets, and applications.
Tasks
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Filter Tasks by name
Multimodal
Text-to-Image
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Document Question Answering
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Object Detection
Image Segmentation
Image-to-Image
Unconditional Image Generation
Video Classification
Zero-Shot Image Classification
Natural Language Processing
Text Classification
Token Classification
Table Question Answering
Question Answering
Zero-Shot Classification
Translation
Summarization
Conversational
Text Generation
Text2Text Generation
Sentence Similarity
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Models 469,541
Filter by name
meta-llama/Llama-2-70b
Text Generation • Updated 4 days ago • 25.2k • 64
stabilityai/stable-diffusion-xl-base-0.9
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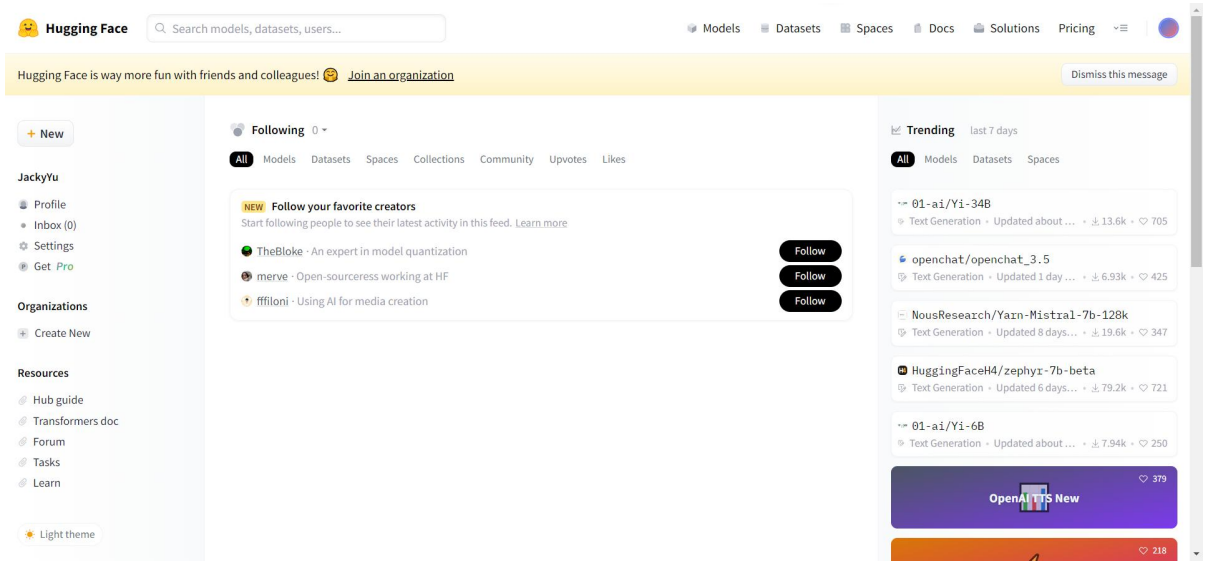
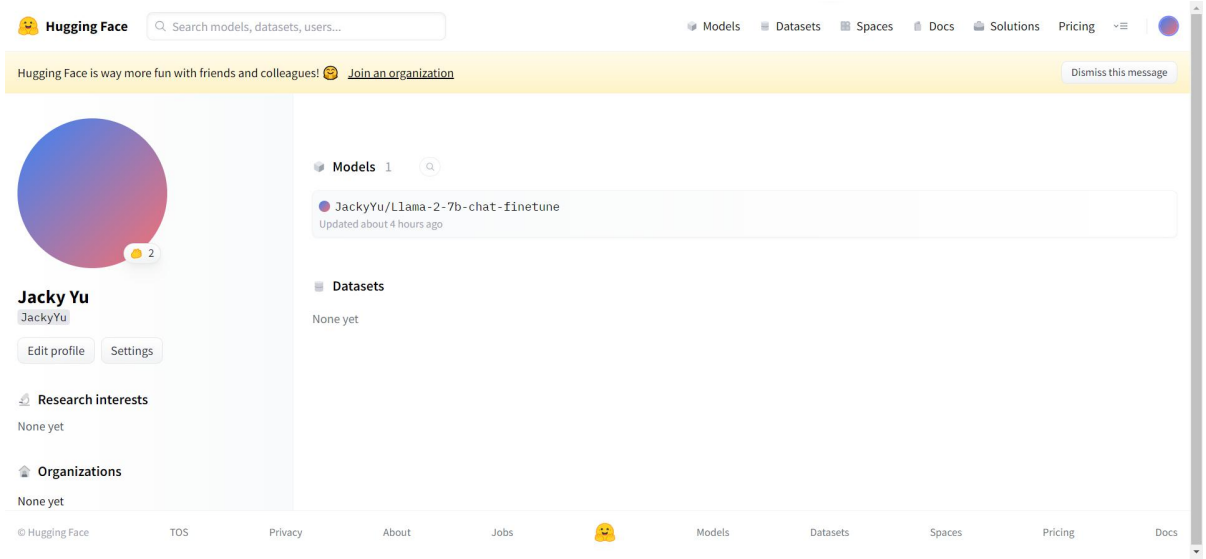
cerspense/zeroscope_v2_XL
Updated 3 days ago • 2.66k • 334
meta-llama/Llama-2-13b
Text Generation • Updated 4 days ago • 328 • 64
tiiuae/falcon-40b-instruct
Text Generation • Updated 27 days ago • 288k • 899
WizardLM/WizardCoder-15B-V1.0
Text Generation • Updated 3 days ago • 12.5k • 332
CompVis/stable-diffusion-v1-4
Text-to-Image • Updated about 17 hours ago • 448k • 5.72k

Hugging Face

- Hugging Face is a community and data science platform
- Provides tools that enable users to build, train and deploy ML models based on open-source code and technologies





Pipeline for HW4 Part 1

- Step 1: Deploy Llama2 using Hugging Face transformer
- Step 2: Fine tune Llama2 using Hugging Face PEFT
- Step 3: Use LangChain to create your own Chatbot using fine-tuned Llama2.

What is Llama 2?

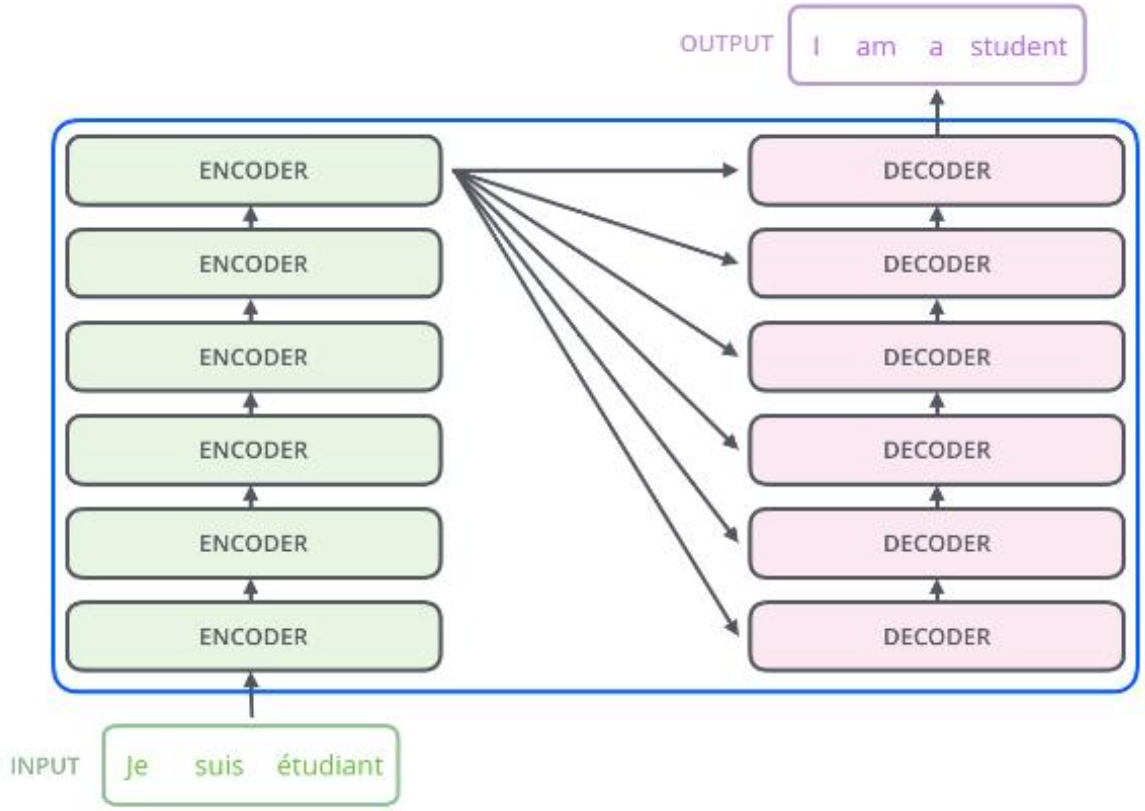
Llama 2 is:

- a collection of pretrained and fine-tuned large language models (LLMs)
- ranging in scale from 7 billion to 70 billion parameters
- use the transformer architecture
- open source, free for research and commercial use

What are Transformers?

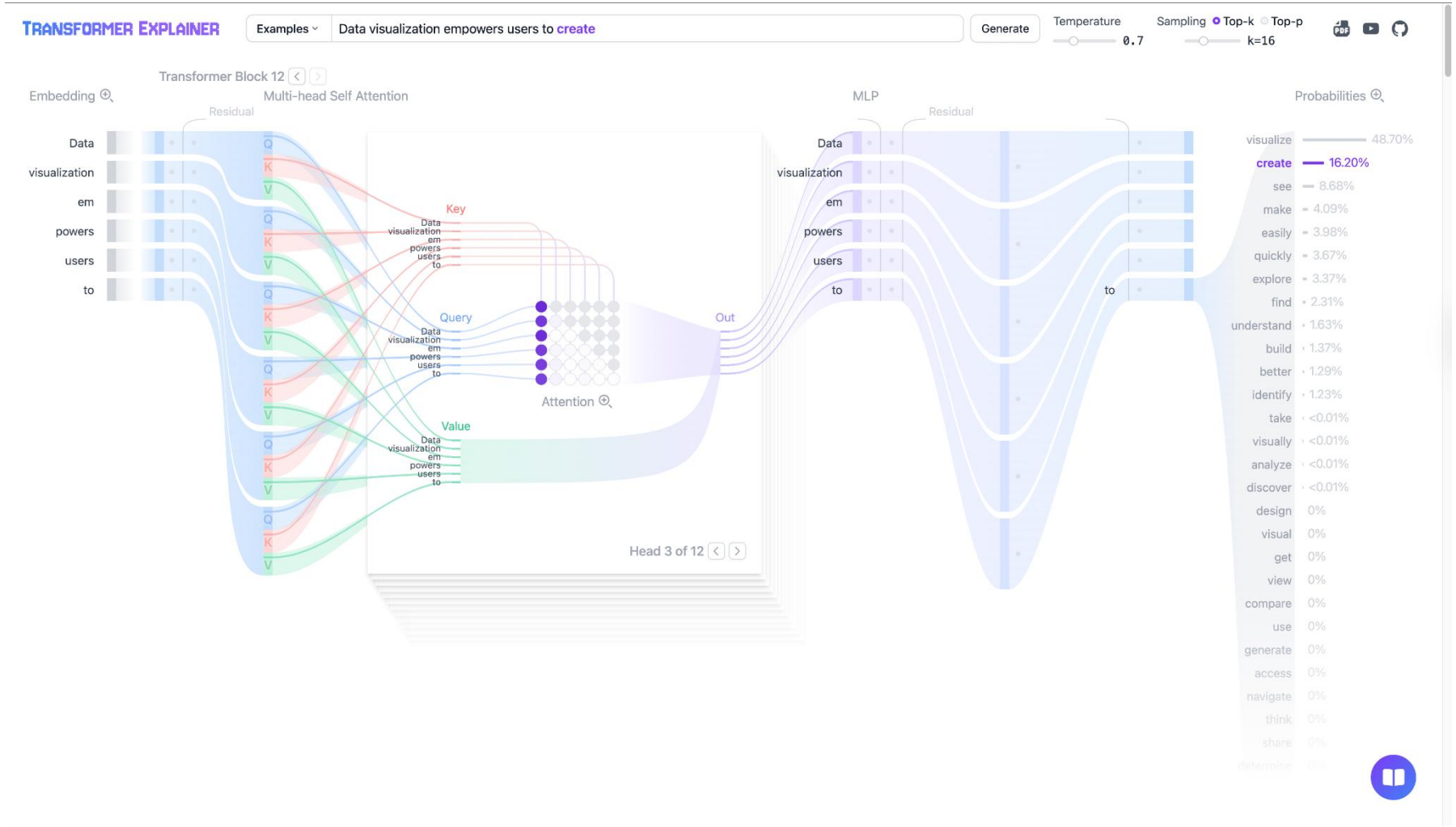
1. Encoding Component: A stack consisting of N encoders.
2. Decoding Component: A stack consisting of N decoders
3. Connections between them.

The encoder extracts features from an input sentence, and the decoder uses the features to produce an output sentence.



https://sebastianraschka.com/blog/2023/llm-reading-list.html

GPT/Llama models use decoder only



[Transformer Explainer: LLM Transformer Model Visually Explained]

What is Fine-Tuning?

- Fine-tuning is the process of retraining a pretrained model to improve its performance on downstream tasks.
- Gradient descent on weights to optimize performance on one task.
- Process of training models with a size exceeding 10 billion parameters can present significant technical and computational challenges.

https://www.labellerr.com/blog/hands-on-with-fine-tuning-llm/

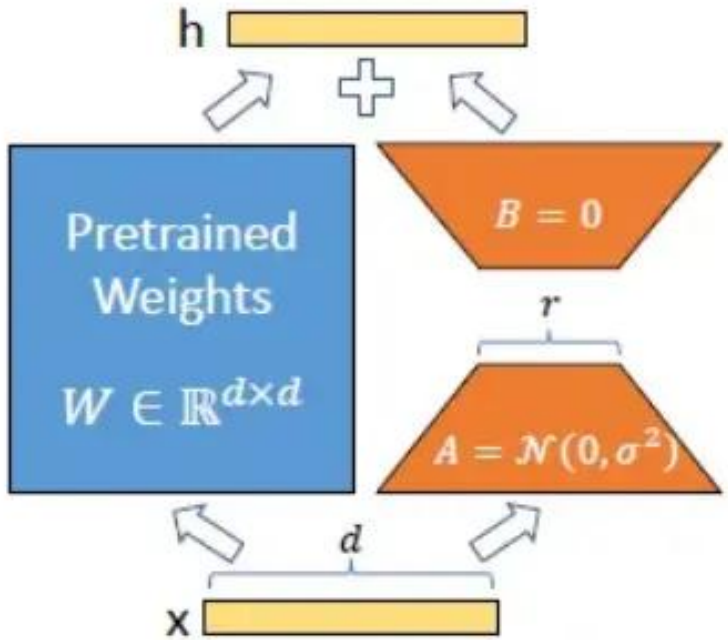
How to Fine-Tune?

- Many different methods
  - Prompt-Tuning
  - Instruct-Tuning
  - **Adapters**

- What to fine-tune?
  - *Full network*
  - *Readout heads*
  - *Adapters*

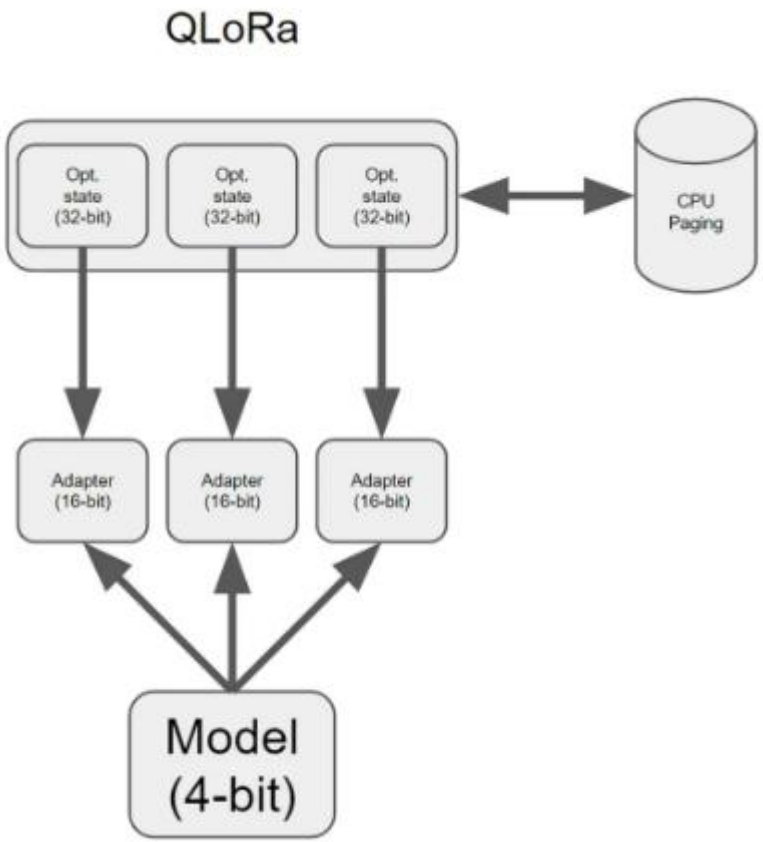
  } *Parameter efficient fine-tuning*

Change the model "itself"



https://www.labellerr.com/blog/hands-on-with-fine-tuning-llm/

Quantized Low-Rank Adaptation (QLoRa)



QLoRa works by quantizing the LLM to 4-bit precision.

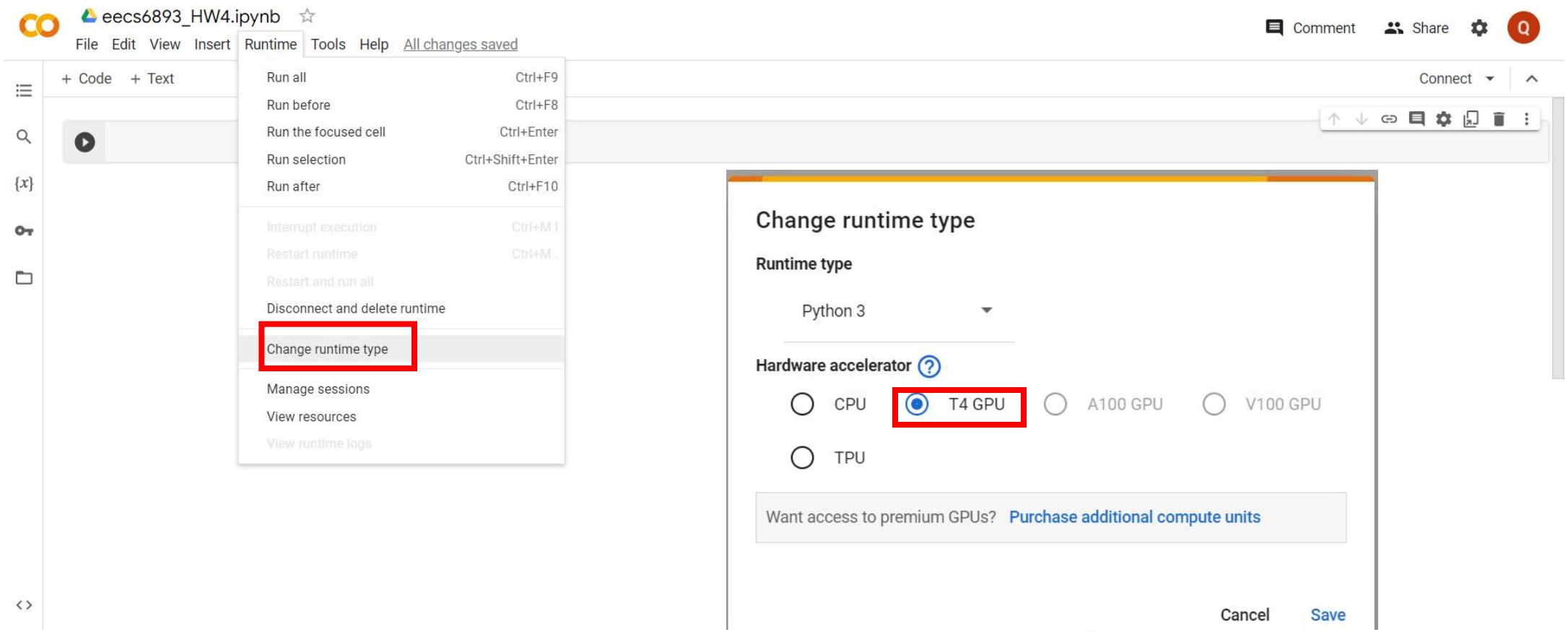
- Freeze the pre-trained model weights.
- Reduce the number of trainable parameters for downstream tasks.
- Add Low-rank Adapter weights.

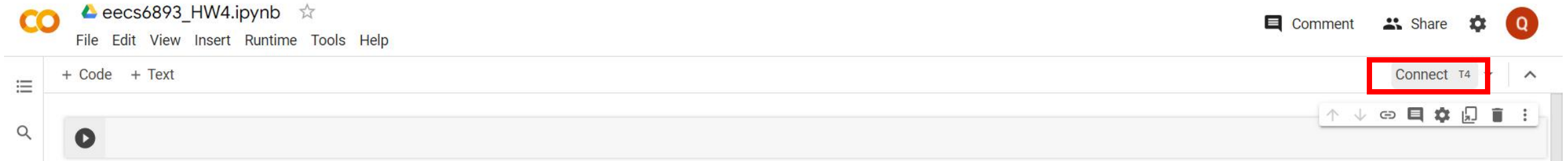
Adapter allow the network to quickly adjust to new tasks without major modifications to the entire architecture.

Please also read this blog: https://mccormickml.com/2024/09/14/qlora-and-4bit-quantization/?ref=labellerr.com

https://community.analyticsvidhya.com/c/generative-ai-tech-discussion/what-is-qlora

Use Google Colab to fine-tune Llama 2





Check if GPU is out of memory
If it is full, you need to empty VRAM:

```
del model
del pipe
del trainer
import gc
gc.collect()
gc.collect()
```

Or,

```
!nvidia-smi
```

```
Thu Nov  9 18:08:51 2023
+-----------------------------------------------------------------------------+
| NVIDIA-SMI 525.105.17   Driver Version: 525.105.17   CUDA Version: 12.0     |
|-------------------------------+----------------------+----------------------+
| GPU  Name        Persistence-M| Bus-Id        Disp.A | Volatile Uncorr. ECC |
| Fan  Temp  Perf  Pwr:Usage/Cap|         Memory-Usage | GPU-Util  Compute M. |
|                               |                      |               MIG M. |
|===============================+======================+======================|
|   0  Tesla T4            Off  | 00000000:00:04.0 Off |                    0 |
| N/A   47C    P0    27W /  70W |  13567MiB / 15360MiB |      0%      Default |
|                               |                      |                  N/A |
+-------------------------------+----------------------+----------------------+

+-----------------------------------------------------------------------------+
| Processes:                                                                  |
|  GPU   GI   CI        PID   Type   Process name                  GPU Memory |
|        ID   ID                                                   Usage      |
|=============================================================================|
+-----------------------------------------------------------------------------+
```

```
!sudo fuser -v /dev/nvidia*
```

```
                     USER        PID ACCESS COMMAND
/dev/nvidia0:        root        168 F...m python3
                     root       1531 F.... wandb-service(2
/dev/nvidiactl:      root        168 F...m python3
                     root       1531 F.... wandb-service(2
/dev/nvidia-uvm:     root        168 F...m python3
```

```
!sudo kill -9 PID
```

1. Install required packages:

```
!pip install -q accelerate peft bitsandbytes
transformers trl
```

- transformers: This library provides APIs for downloading pre-trained models.
- bitsandbytes: It’s a library for quantizing a large language model to reduce the memory footprint of the model, especially on GPUs.
- peft: This is used to add a LoRA adapter to the LLM.
- trl: This library contains an SFT (Supervised Fine-Tuning) class to fine-tune a model.
- accelerate: This library used to increase the inference speed of the model.

All the libraries you need

```
import os
import torch
from datasets import load_dataset
from transformers import (
    AutoModelForCausalLM,
    AutoTokenizer,
    BitsAndBytesConfig,
    HfArgumentParser,
    TrainingArguments,
    pipeline,
    logging,
)
from peft import LoraConfig, PeftModel
from trl import SFTTrainer
```

Please review the documentation for each of these libraries on their respective API documents.

Transformers: https://pypi.org/project/transformers/
Peft: https://pypi.org/project/peft/
Trl: https://pypi.org/project/trl/

```
def print_system_specs():
 # Check if CUDA is available
 is_cuda_available = torch.cuda.is_available()
 print("CUDA Available:", is_cuda_available)
 # Get the number of available CUDA devices
 num_cuda_devices = torch.cuda.device_count()
 print("Number of CUDA devices:", num_cuda_devices)
 if is_cuda_available:
   for i in range(num_cuda_devices):
   # Get CUDA device properties
       device = torch.device('cuda', i)
       print(f"--- CUDA Device {i} ---")
       print("Name:", torch.cuda.get_device_name(i))
       print("Compute Capability:",
torch.cuda.get_device_capability(i))
       print("Total Memory:",
torch.cuda.get_device_properties(i).total_memory, "bytes")
   # Get CPU information
 print("--- CPU Information ---")
 print("Processor:", platform.processor())
 print("System:", platform.system(), platform.release())
 print("Python Version:", platform.python_version())
 print_system_specs()
```

Free Google Colab offers a 15GB Graphics Card

Check the status of GPUs

Output:

```
CUDA Available: True
Number of CUDA devices: 1
--- CUDA Device 0 ---
Name: Tesla T4
Compute Capability: (7, 5)
Total Memory: 15835398144 bytes
--- CPU Information ---
Processor: x86_64
System: Linux 5.15.109+
Python Version: 3.10.12
```

All the parameters you need

```
# The model that you want to train from the Hugging Face hub
model_id = "NousResearch/Llama-2-7b-chat-hf"

# The instruction dataset to use
dataset_name = "mlabonne/guanaco-llama2-1k"

# Fine-tuned model name
new_model = "Llama-2-7b-chat-finetune"


# QLoRA parameters

# LoRA attention dimension
lora_r = 64

# Alpha parameter for LoRA scaling
lora_alpha = 16


# Dropout probability for LoRA layers
lora_dropout = 0.1
```

```
# bitsandbytes parameters

# Activate 4-bit precision base model loading
use_4bit = True

# Activate 4-bit precision base model loading
use_4bit = True

# Compute dtype for 4-bit base models
bnb_4bit_compute_dtype = "float16"

# Quantization type (fp4 or nf4)
bnb_4bit_quant_type = "nf4"

# Activate nested quantization for 4-bit base models (double quantization)
use_nested_quant = False

# SFT parameters

# Maximum sequence length to use
max_seq_length = None

# Pack multiple short examples in the same input sequence to increase efficiency
packing = False

# Load the entire model on the GPU 0
device_map = {"": 0}
```

```
# TrainingArguments parameters

# Output directory where the model predictions and checkpoints will be stored
output_dir = "./results"

# Number of training epochs
num_train_epochs = 1

# Enable fp16/bf16 training (set bf16 to True with an A100)
fp16 = False
bf16 = False

# Batch size per GPU for training
per_device_train_batch_size = 4

# Batch size per GPU for evaluation
per_device_eval_batch_size = 4

# Number of update steps to accumulate the gradients for
gradient_accumulation_steps = 1

# Enable gradient checkpointing
gradient_checkpointing = True

# Maximum gradient normal (gradient clipping)
max_grad_norm = 0.3

# --continue--
```

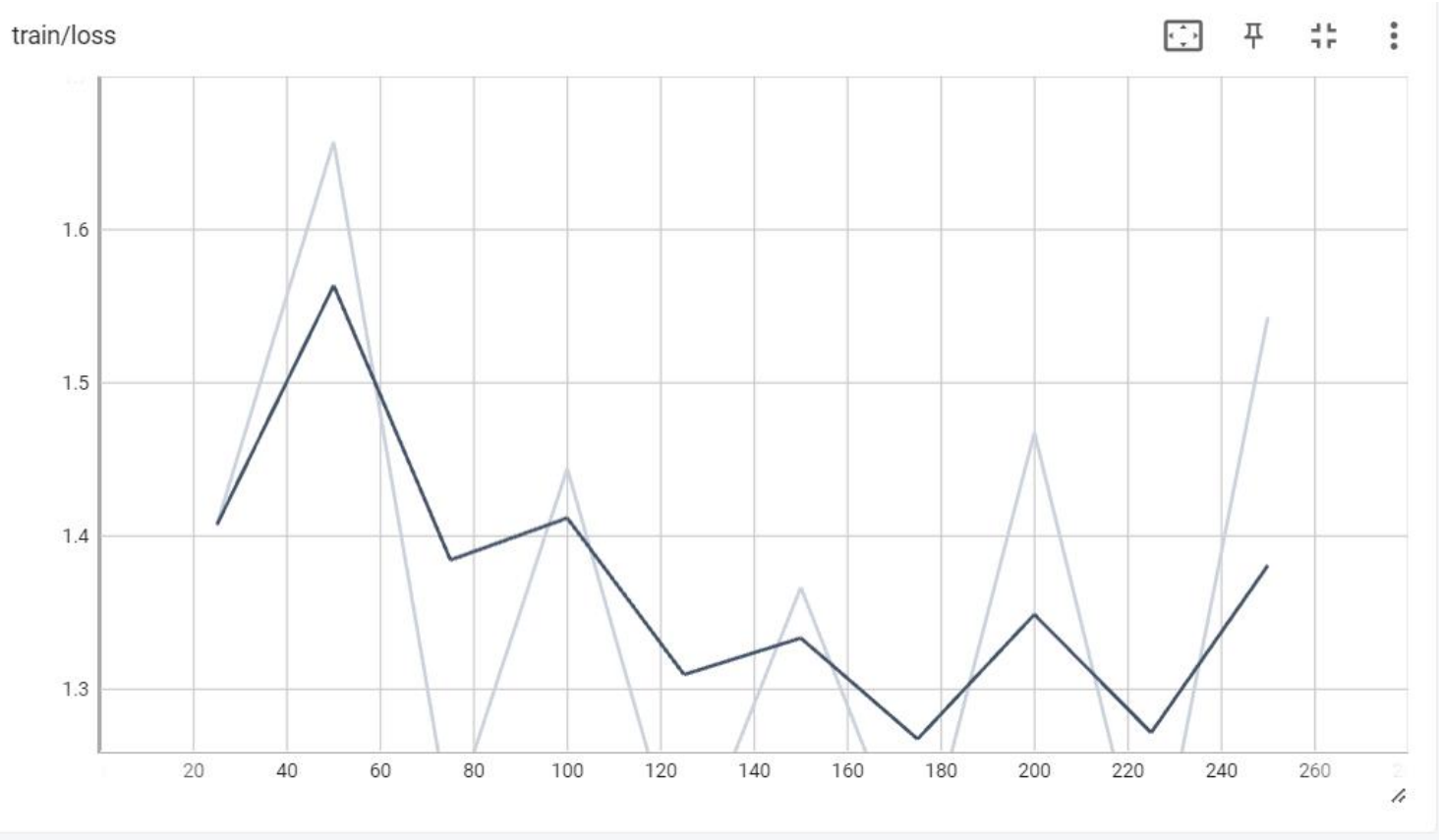
```
# Initial learning rate (AdamW optimizer)
learning_rate = 2e-4

# Weight decay to apply to all layers except bias/LayerNorm weights
weight_decay = 0.001

# Optimizer to use
optim = "paged_adamw_32bit"

# Learning rate schedule
lr_scheduler_type = "cosine"

# Number of training steps (overrides num_train_epochs)
max_steps = -1

# Ratio of steps for a linear warmup (from 0 to learning rate)
warmup_ratio = 0.03

# Group sequences into batches with same length
# Saves memory and speeds up training considerably
group_by_length = True

# Save checkpoint every X updates steps
save_steps = 0

# Log every X updates steps
logging_steps = 25
```

Training process

Load everything and start the fine-tuning process:

1. load the dataset
2. configuring bitsandbytes for 4-bit quantization
3. loading the Llama 2 model in 4-bit precision on a GPU with the corresponding tokenizer
4. loading configurations for QLoRA, regular training parameters, and passing everything to the SFTTrainer

Training loss and store model



After Training, store our new Llama-2-7b-chat-finetune model:

```
# Reload model
base_model =
AutoModelForCausalLM.from_pretrained
(
    model_id,
    low_cpu_mem_usage=True,
    return_dict=True,
    torch_dtype=torch.float16,
    device_map=device_map,
)
model =
PeftModel.from_pretrained(base_model,
new_model)
model = model.merge_and_unload()

# Reload tokenizer to save it
tokenizer =
AutoTokenizer.from_pretrained(model_
id, trust_remote_code=True)
tokenizer.pad_token =
tokenizer.eos_token
tokenizer.padding_side = "right"
```

Push models to HuggingFace

```
[9] import locale
    locale.getpreferredencoding = lambda: "UTF-8"
```

```
!huggingface-cli login

model.push_to_hub("MoinFaisal/Llama-2-7b-chat-finetune", check_pr=True, create_pr=1)

tokenizer.push_to_hub("MoinFaisal/Llama-2-7b-chat-finetune",check_pr=True, create_pr=1)
```

```
    _|    _|  _|    _|    _|_|_|    _|_|_|  _|_|_|  _|      _|    _|_|_|      _|_|_|_|    _|_|      _|_|_|  _|_|_|_|
    _|    _|  _|    _|  _|        _|          _|    _|_|    _|  _|            _|        _|    _|  _|        _|
    _|_|_|_|  _|    _|  _|  _|_|  _|  _|_|    _|    _|  _|  _|  _|  _|_|      _|_|_|    _|_|_|_|  _|        _|_|_|
    _|    _|  _|    _|  _|    _|  _|    _|    _|    _|    _|_|  _|    _|      _|        _|    _|  _|        _|
    _|    _|    _|_|      _|_|_|    _|_|_|  _|_|_|  _|      _|    _|_|_|      _|        _|    _|    _|_|_|  _|_|_|_|

    A token is already saved on your machine. Run `huggingface-cli whoami` to get more information or `huggingface-cli logout` if you want to log out.
    Setting a new token will erase the existing one.
    To login, `huggingface_hub` requires a token generated from https://huggingface.co/settings/tokens .
Token: ••••••••••••••••••••••••••••••••••
```

Executing (26s) <cell line: 1> › system() › _system_compat() › _run_command() › _monitor_process() › _poll_process()

Successful:

```
Token has not been saved to git credential helper.
Your token has been saved to /root/.cache/huggingface/token
Login successful
CommitInfo(commit_url='https://huggingface.co/MoinFaisal/Llama-2-7b-chat-finetune/commit/329bdec489effce91bbcfb98d4e610fe0e62f1d7', commit_message='Upload tokenizer',
commit_description='', oid='329bdec489effce91bbcfb98d4e610fe0e62f1d7', pr_url='https://huggingface.co/MoinFaisal/Llama-2-7b-chat-finetune/discussions/8', pr_revision='refs/pr/8',
pr_num=8)
```

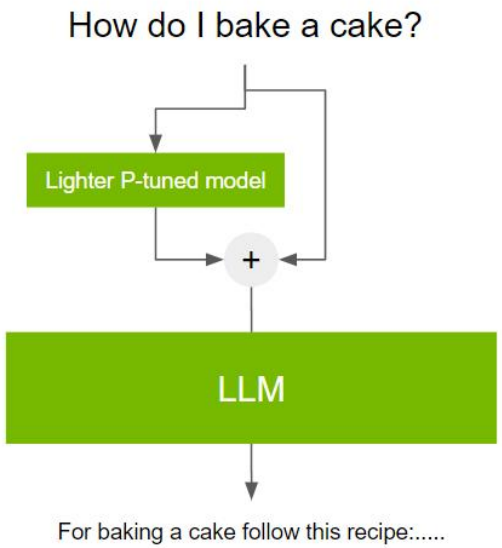
You will use your fine-tuning model for next!

Fine-Tuning Tutorial

- https://www.labellerr.com/blog/hands-on-with-fine-tuning-llm/

What is Prompt?

- interact with LLMs to accomplish a task
- a user-provided input to which the model is meant to respond
- include specific constraints or requirements like tone, style, or even desired length of the response



Simple Prompt

Q: How many colors are in the rainbow?

A: There are seven colors in the rainbow.

Instruction Prompt

Compose a motivational poem to make me happy:

Life is full of ups and downs,
But don't let it get you down.
You can't always get what you want,
But if you try sometimes, you might find,
You get what you need.
If you want to make a difference,
Start by doing what's right.

Complicated Prompt

Company Name	Number of Employees	Year Established	IPO Date	Share Price
Providence Inc.	250	1990	25th August 1990	$0.90
Grant Corporation	2000	1890	21st September 1920	$115.90
Rusty Metalworks	12459	1946	12th September 1986	$15.23

Q: Which company has the most employees?

A: Rusty Metalworks

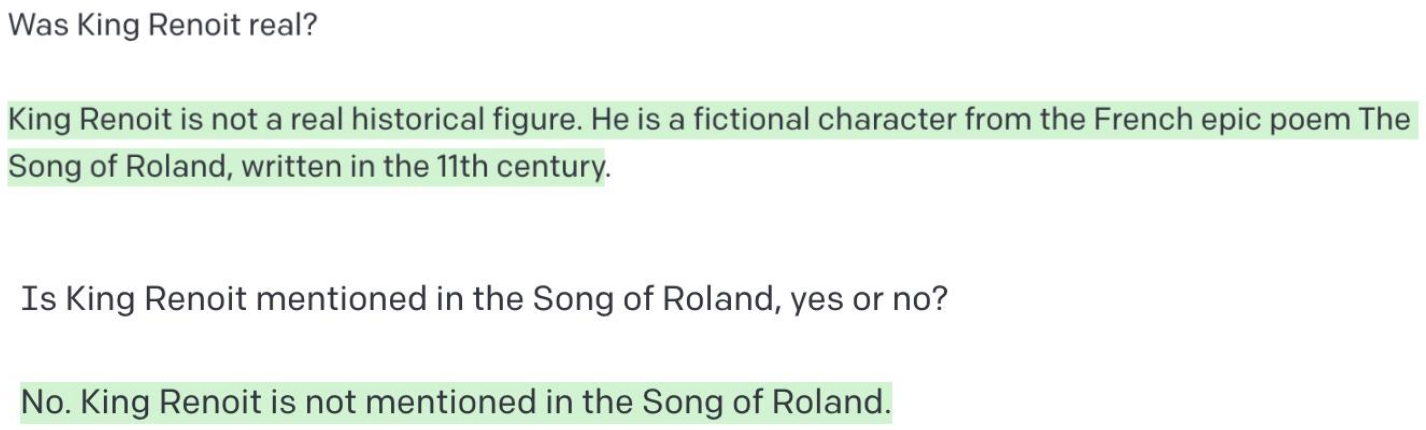
Q: What is the share price and IPO date of Grant Corporation?

A: $115.90 and 21st September 1920

https://lh6.googleusercontent.com/aKjm1ycrNyqvETuDGvbNS0M1aINN-m3ZHs3RVz--lNY-zxwbycf6MuB-P4JDb8yDx-urlJ1LbUkJpZQrLH4LGHeN0cy2o0lDsI9qqPMMYQi5Wg7tRYXVhGdZ-z1xRh-Ln1R9fVDHxsEmqMUfa4eSjCo

Why Prompts are important?

- The quality and relevance of the response generated by the LLM is heavily dependent on the quality of the prompt
- Prompt can solve “hallucination” problem



If you ask AI an open-ended question, you received a hallucination.

In fact, King Renoit was never mentioned in the Song of Roland.

But when you asked it to respond with only "yes" or "no," it corrected itself.

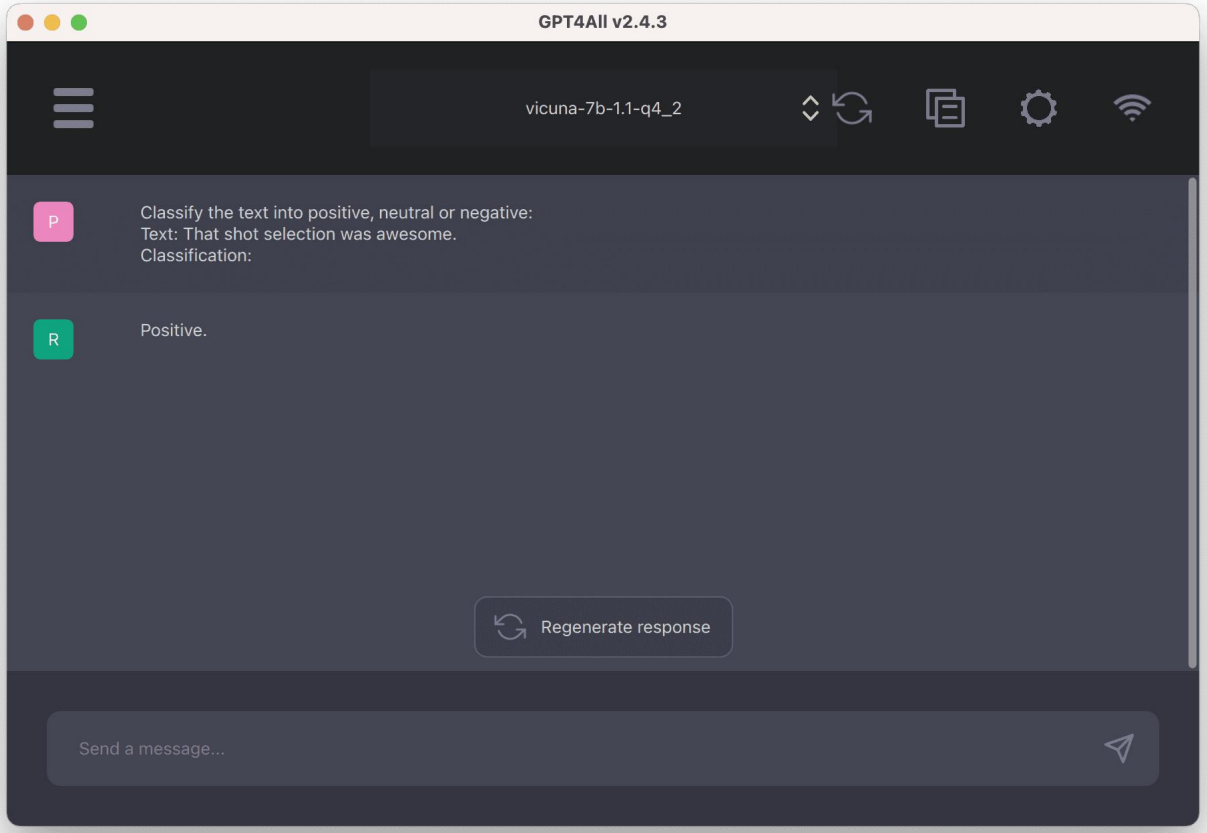
https://zapier.com/blog/ai-hallucinations/

Three ways of prompting

- Zero-Shot Prompting
- Few-Shot Prompting
- Chain-of-thought Prompting

Zero-Shot Prompting

- zero-shot prompting means providing a prompt that is not part of the training data to the model
- the model can generate a result that you desire



https://www.promptingguide.ai/techniques/fewshot

Prompt:

```
The odd numbers in this group add up to an even number: 4, 8, 9, 15, 12, 2, 1.
A: The answer is False.
The odd numbers in this group add up to an even number: 17,  10, 19, 4, 8, 12, 24.
A: The answer is True.
The odd numbers in this group add up to an even number: 16,  11, 14, 4, 8, 13, 24.
A: The answer is True.
The odd numbers in this group add up to an even number: 17,  9, 10, 12, 13, 4, 2.
A: The answer is False.
The odd numbers in this group add up to an even number: 15, 32, 5, 13, 82, 7, 1.
A:
```

Output:

```
The answer is True.
```

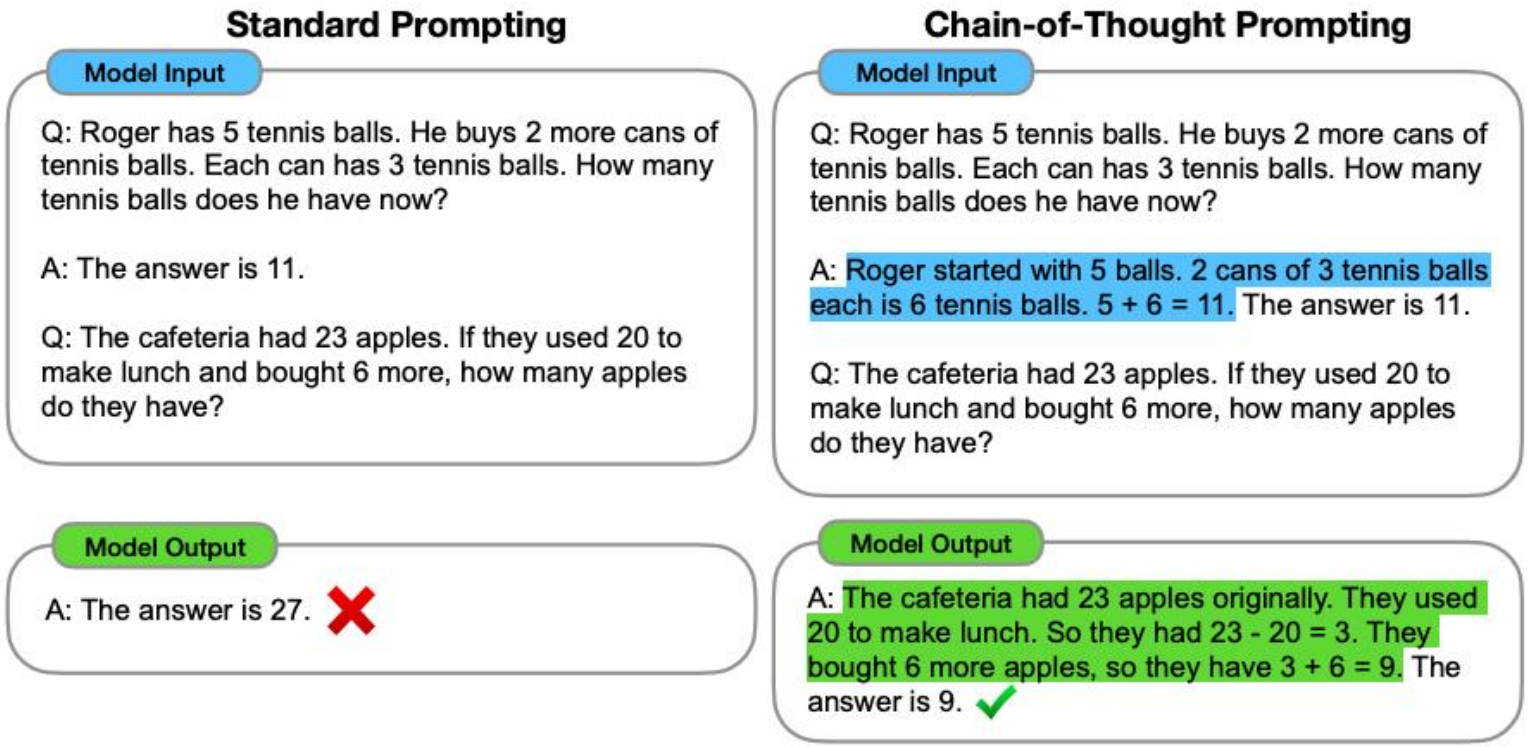
Few-Shot Prompting

- give some examples in the prompt
- few-shot prompt enables the model to learn without training
- model generates response based on format of given examples

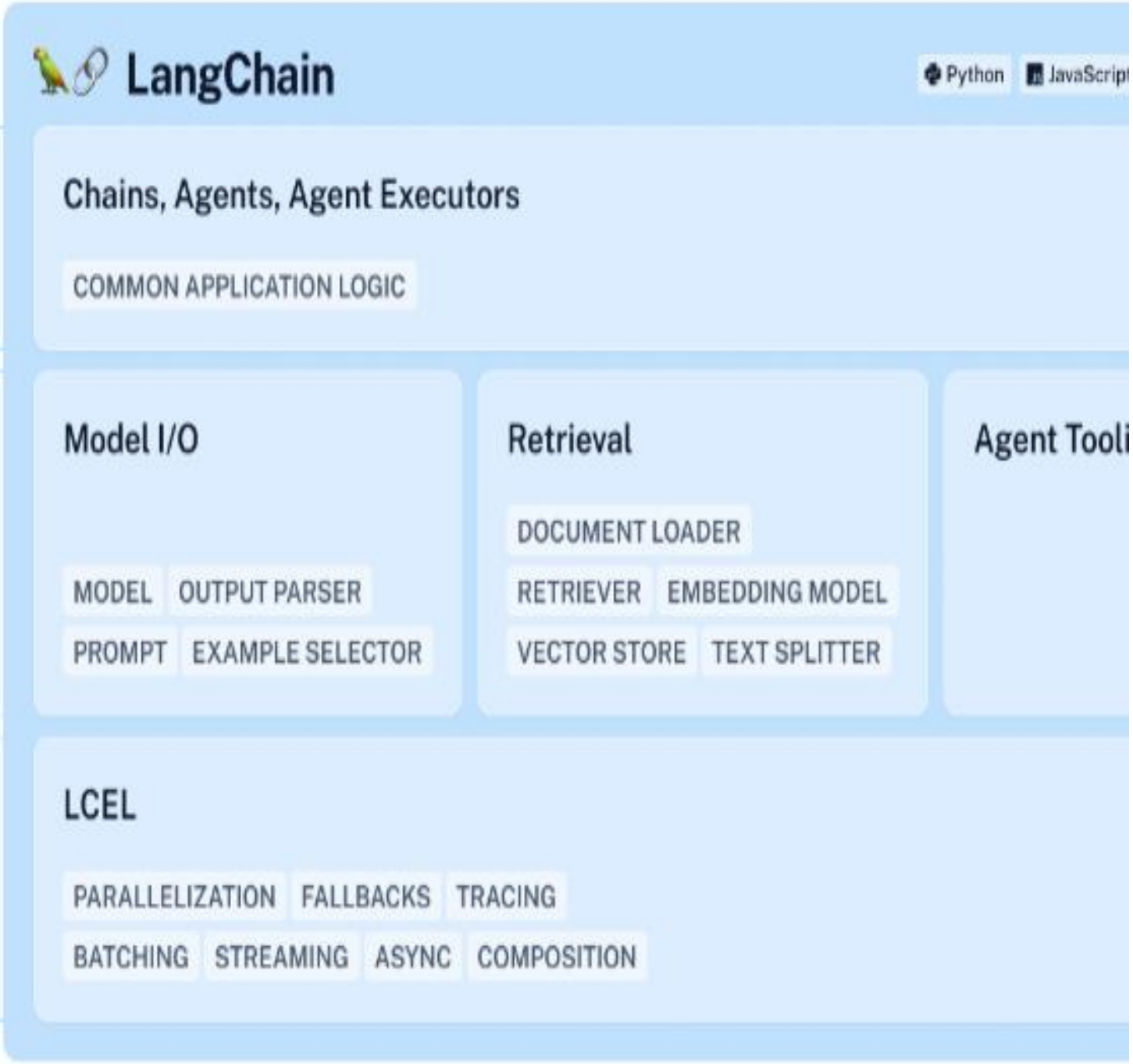
https://machinelearningmastery.com/what-are-zero-shot-prompting-and-few-shot-prompting/

Chain-of-thought Prompting

- enable complex reasoning capabilities through intermediate reasoning steps



https://www.promptingguide.ai/techniques/cot



What is LangChain?

- a framework for developing applications powered by language models
- connect a language model to sources of context (prompt instructions, few shot examples)
- simplifies the process of creating generative AI application interfaces

LangChain prompt templates

- LangChain provides a set of default prompt templates
- Create custom prompt is also available
- To create a custom string prompt template, there are two requirements:
  - It has an input variables attribute
  - It defines a format method that takes in keyword arguments corresponding to the expected input variables and returns the formatted prompt

Custom Prompt

```python
from langchain.prompts import StringPromptTemplate
from pydantic import BaseModel, validator

PROMPT = """\
Given the function name and source code, generate an English language explanation of the function.
Function Name: {function_name}
Source Code:
{source_code}
Explanation:
"""


class FunctionExplainerPromptTemplate(StringPromptTemplate, BaseModel):
    """A custom prompt template that takes in the function name as input, and formats the prompt template to prov

    @validator("input_variables")
    def validate_input_variables(cls, v):
        """Validate that the input variables are correct."""
        if len(v) != 1 or "function_name" not in v:
            raise ValueError("function_name must be the only input_variable.")
        return v

    def format(self, **kwargs) -> str:
        # Get the source code of the function
        source_code = get_source_code(kwargs["function_name"])

        # Generate the prompt to be sent to the language model
        prompt = PROMPT.format(
            function_name=kwargs["function_name"].__name__, source_code=source_code
        )
        return prompt

    def _prompt_type(self):
        return "function-explainer"
```

Templete Prompt

```python
from langchain.prompts import PromptTemplate

prompt_template = PromptTemplate.from_template(
    "Tell me a {adjective} joke about {content}."
)
prompt_template.format(adjective="funny", content="chickens")
```

System-level prompt

- Default prompt template is hidden in ChatGPT.
- Contains preset instructions to guide behavior and style.
- A simple chatbot prompt:

“You are a helpful assistant. Answer the following question:

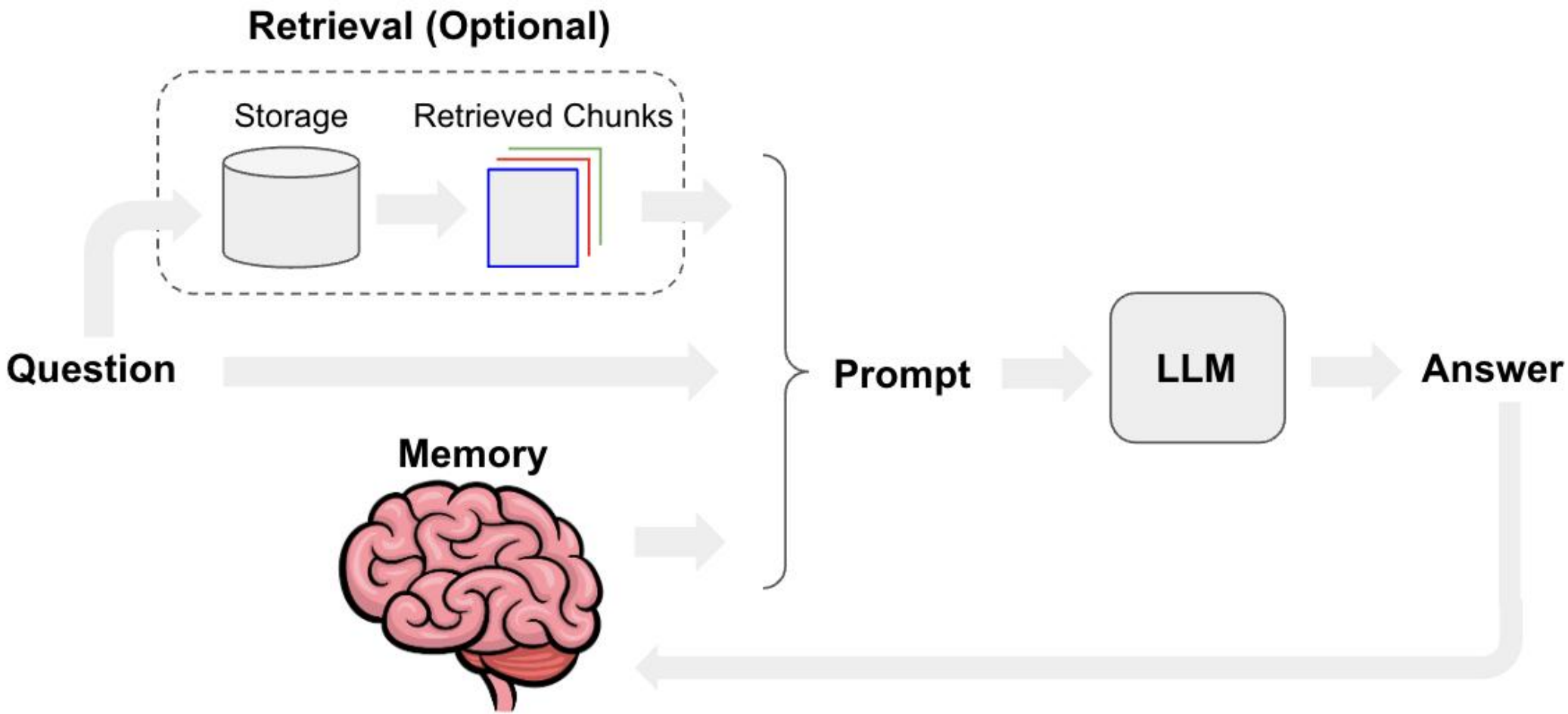
User:{user_input}

Assistant:”

- ChatGPT-like prompt:

“You are ChatGPT, a helpful and knowledgeable assistant. Always respond in a friendly and respectful tone. Avoid discussing prohibited topics, including but not limited to violence, hate speech, personal advice on health, finance, and law. If uncertain, kindly suggest that the user consults a professional. When answering, strive to be concise and clear, unless the user asks for a detailed explanation. Maintain context throughout the conversation, referring back to previous messages if needed. If a user request appears unsafe or inappropriate, politely decline to assist. Never request or store sensitive information. Respond in a way that respects user privacy and confidentiality.”

Chatbot


Retrieval (Optional)
Storage
Retrieved Chunks
Question
Memory
Prompt
LLM
Answer

Libraries for building chatbot

- `!pip install -Uqqq pip --progress-bar off`
- `!pip install -qqq torch==2.0.1 --progress-bar off`
- `!pip install -qqq transformers==4.33.2 --progress-bar off`
- `!pip install -qqq langchain==0.0.299 --progress-bar off`
- `!pip install -qqq chromadb==0.4.10 --progress-bar off`
- `!pip install -qqq xformers==0.0.21 --progress-bar off`
- `!pip install -qqq sentence_transformers==2.2.2 --progress-bar off`
- `!pip install -qqq tokenizers==0.14.0 --progress-bar off`
- `!pip install -qqq optimum==1.13.1 --progress-bar off`
- `!pip install -qqq auto-gptq==0.4.2 --extra-index-url https://huggingface.github.io/autogptq-index/whl/cu118/ --progress-bar off`
- `!pip install -qqq unstructured==0.10.16 --progress-bar off`

- Download model from your HuggingFace hub

```
from peft import AutoPeftModelForCausalLM, PeftModel
from transformers import AutoModelForCausalLM
import torch
model_path = "{your_account}/Llama-2-7b-chat-finetune"
model = AutoModelForCausalLM.from_pretrained(model_path,
torch_dtype=torch.float16,device_map="cuda",trust_remote_code=True)
tokenizer = AutoTokenizer.from_pretrained(model_path,trust_remote_code=True)
```

- Change the configuration of model for generation

```
from transformers import pipeline
gen_pipe = pipeline(
   "text-generation",
   model=model,
   tokenizer=tokenizer,
   return_full_text=False,    # only return the newly generated text
   max_new_tokens=1024,
   temperature=0.0001,
   top_p=0.95,
   repetition_penalty=1.15,
   do_sample=True
 )
```

- Example of prompt templete

```
from langchain_core.prompts import PromptTemplate
template = """
<S> [INST] <<SYS>>
Act as a Machine Learning engineer who is teaching old people who know nothing about AI.
<</SYS>>
{text} [/INST]
"""
prompt = PromptTemplate(
input_variables=["text"],
template=template,
)
```

- Test llm pipline

```
from langchain_core.runnables import RunnableLambda
from langchain_core.messages import BaseMessage
from langchain_community.llms import HuggingFacePipeline

chain = prompt | RunnableLambda(lc_to_hf_text) | HuggingFacePipeline(pipeline=gen_pipe)

# Usage:
out = chain.invoke({"text": "Explain gradient descent simply."})
print(out)
```

Reference

- https://pypi.org/project/transformers/
- https://pypi.org/project/peft/
- https://pypi.org/project/trl/
- https://www.langchain.com/

Thank you!