Assignment 4: Retrieval-Augmented Generation with LangChain

2024 NTHU Natural Language Processing

Hung-Yu Kao

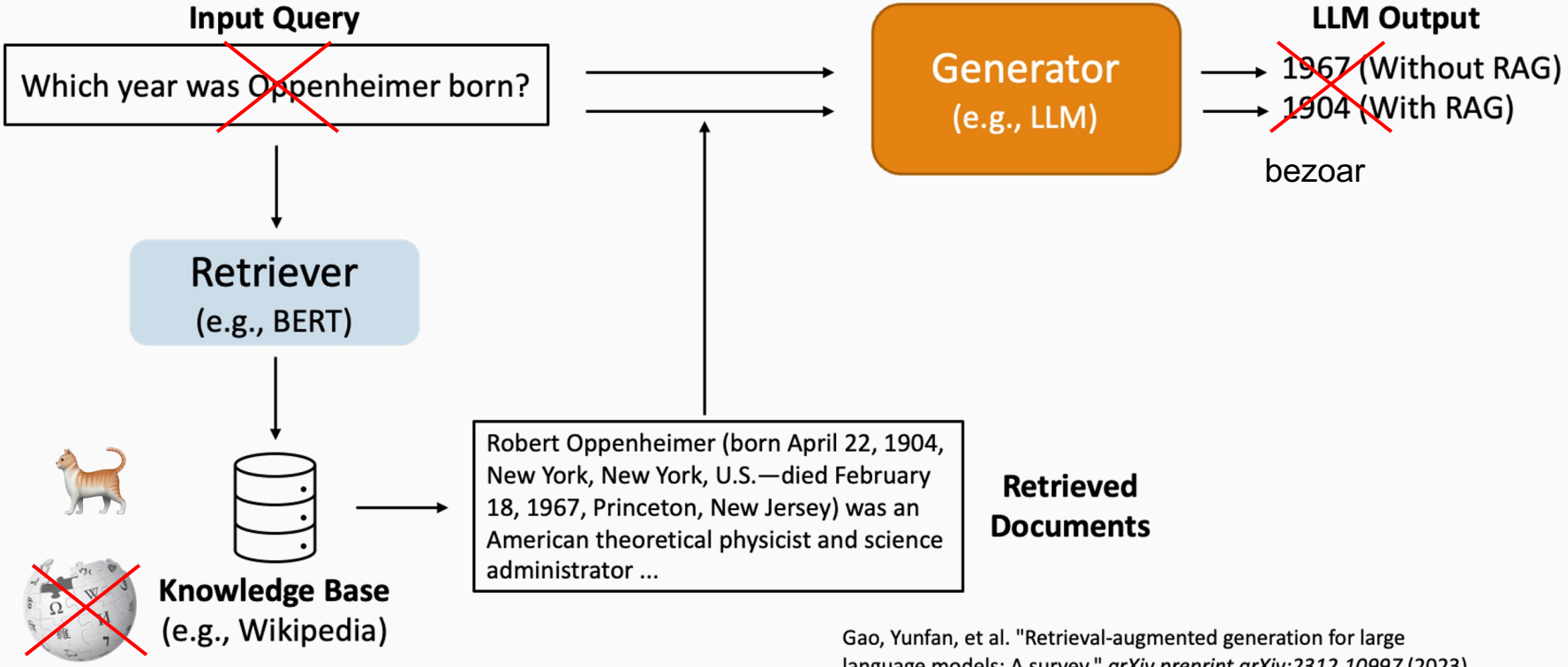
IKM Lab TAs

Assignment Description

- Task: Retrieval-Augmented Generation (RAG) for **Question Answering**
- Database: Cats' knowledge in texts
- Inputs: **Ten questions** about cats' knowledge
- Answer: Short answers for the ten questions (evaluation: exact matching)
- Restricted models
    - Generator: Llama-3.2-1B (freezed)

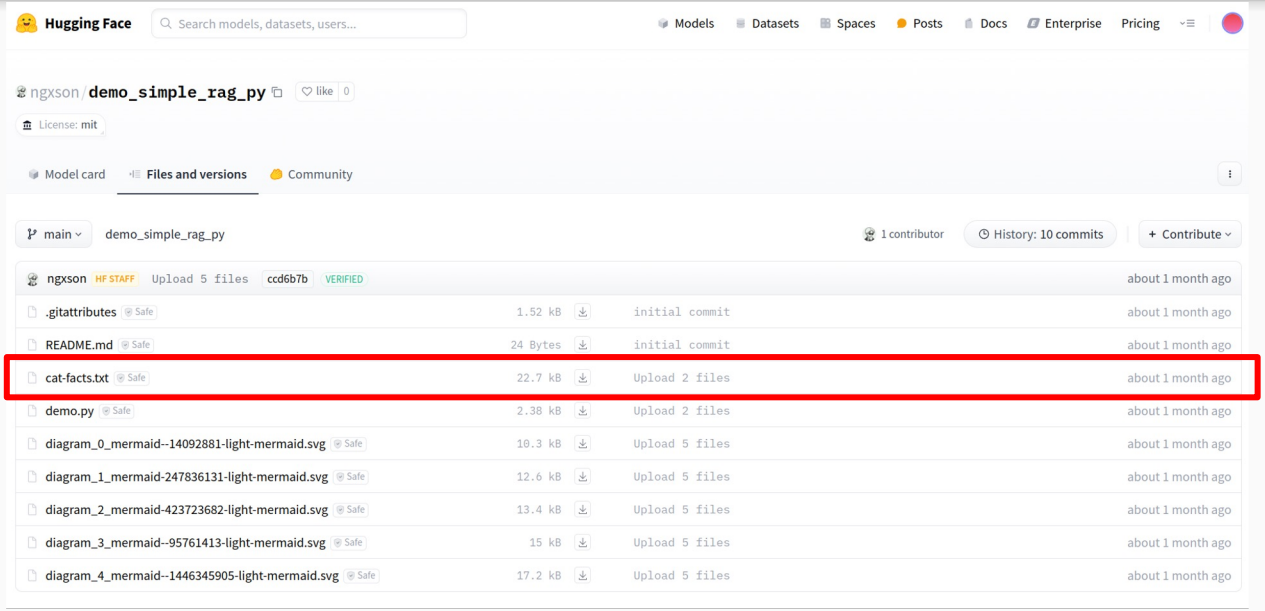
Retrieval-Augmented Generation (RAG)


What is the technical term for a cat's hairball?



Gao, Yunfan, et al. "Retrieval-augmented generation for large language models: A survey." *arXiv preprint arXiv:2312.10997* (2023).

Dataset: Cat-facts



The dataset is presented in ngxson/demo_simple_rag_py

Dataset

Cat-facts dataset

- Database size: 150 facts
- Each fact is represented as a sentence.
  - E.g., When a cat chases its prey, it keeps its head level. Dogs and humans bob their heads up and down.
  - E.g., The technical term for a cat’s hairball is a “bezoar.”
  - …

Construction for Questions and Answers

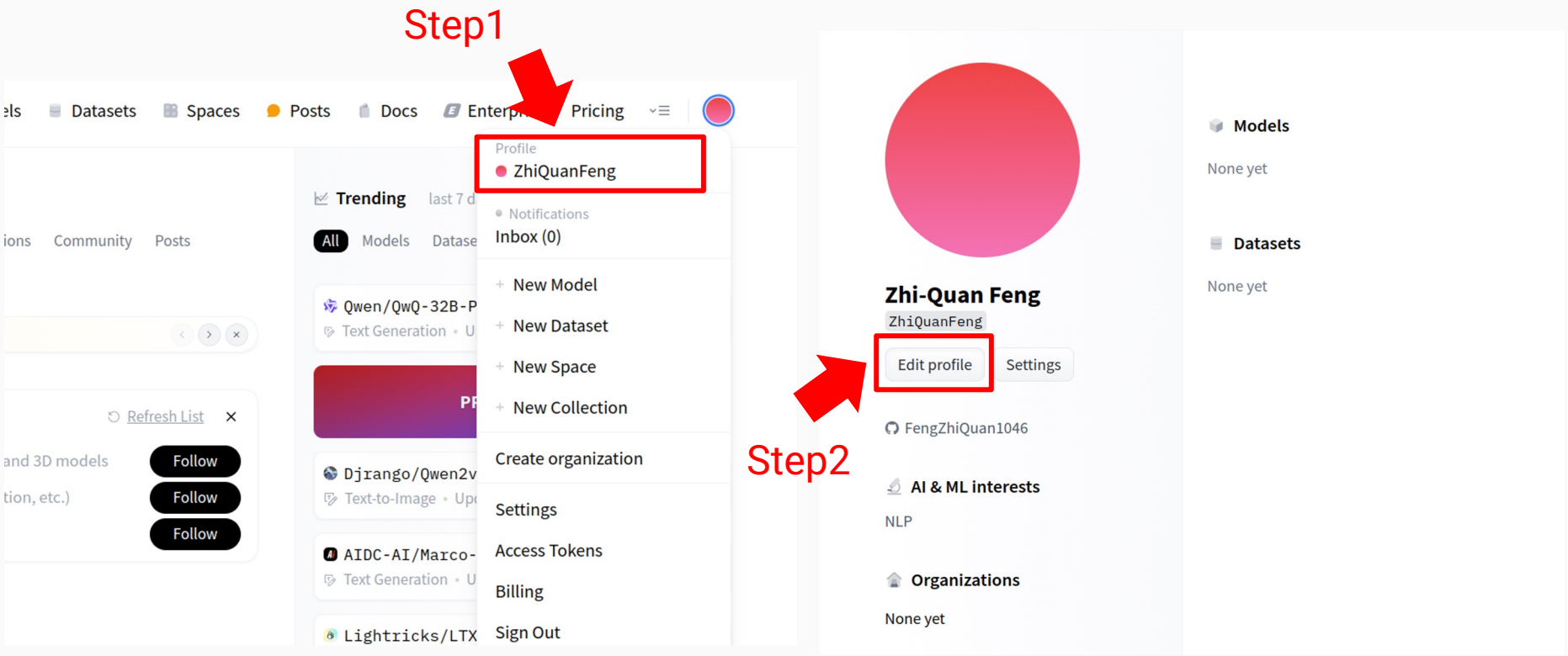
Index	Question	Answer Sentence in the database	Answer we set
1	How much of a day do cats spend sleeping on average?	On average, cats spend 2/3 of every day sleeping.	2/3
2	What is the technical term for a cat's hairball?	The technical term for a cat's hairball is a "bezoar."	bezoar
3	What do scientists believe caused cats to lose their sweet tooth?	Scientists believe this is due to a mutation in a key taste receptor.	a mutation in a key taste receptor
4	What is the top speed a cat can travel over short distances?	A cat can travel at a top speed of approximately 31 mph (49 km) over a short distance.	31 mph or 49 km
5	What is the name of the organ in a cat's mouth that helps it smell?	Besides smelling with their nose, cats can smell with an additional organ called the Jacobson's organ, located in the upper surface of the mouth.	Jacobson's organ

Construction for Questions and Answers

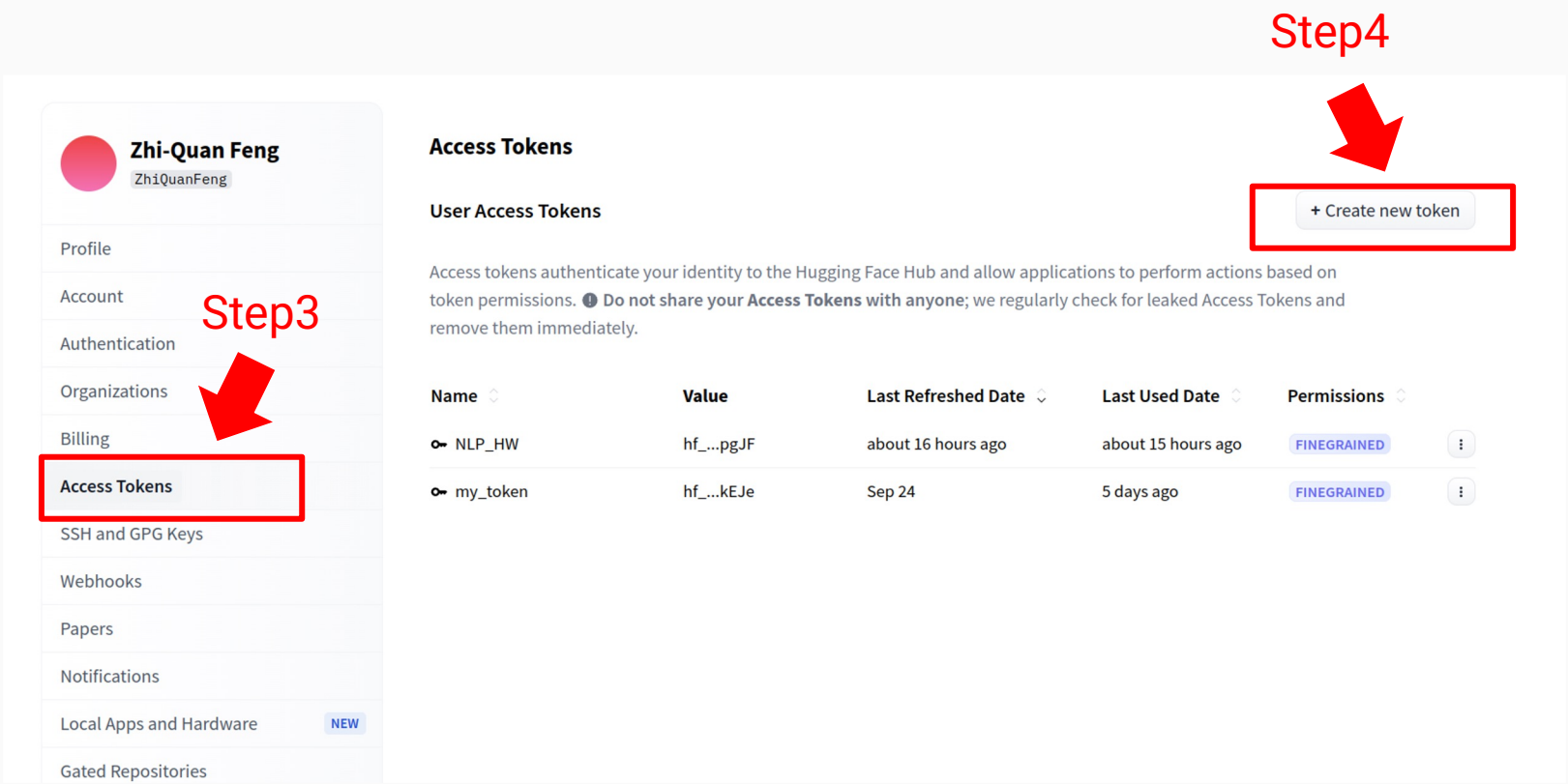
Index	Question	Answer Sentence in the database	Answer we set
6	Which wildcat is considered the ancestor of all domestic cats?	The ancestor of all domestic cats is the African Wild Cat which still exists today.	the African Wild Cat
7	What is the group term for cats?	A group of cats is called a “clowder.”	clowder
8	How many different sounds can cats make?	Cats make about 100 different sounds.	100
9	What is the name of the first cat in space?	The first cat in space was a French cat named Felicette (a.k.a. “Astrocat”) In 1963, France blasted the cat into outer space.	Felicette or Astrocat
10	How many toes does a cat have on its back paws?	Cats have five toes on each front paw, but only four toes on each back paw.	four

Code (hints only)

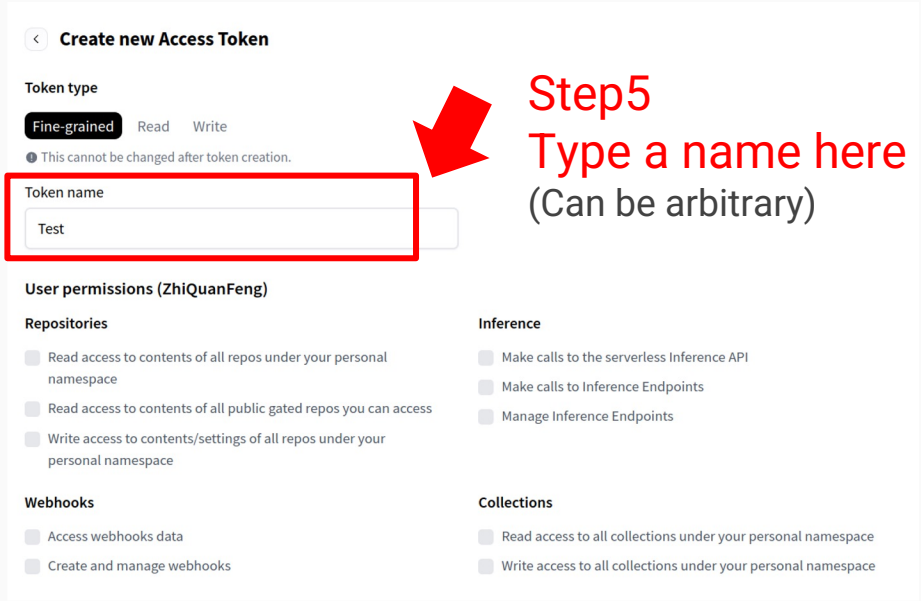
Connect to Huggingface (1/4)



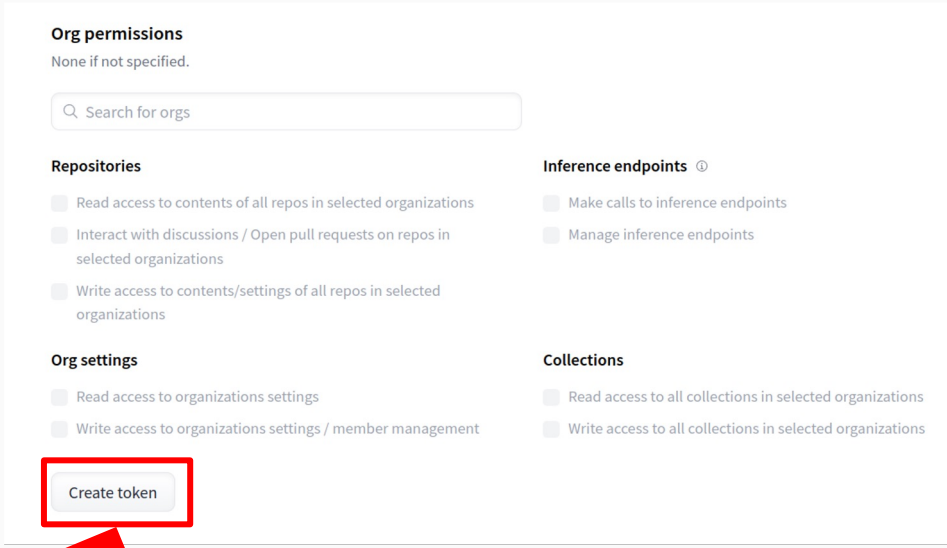
Connect to Huggingface (2/4)



Connect to Huggingface (3/4)

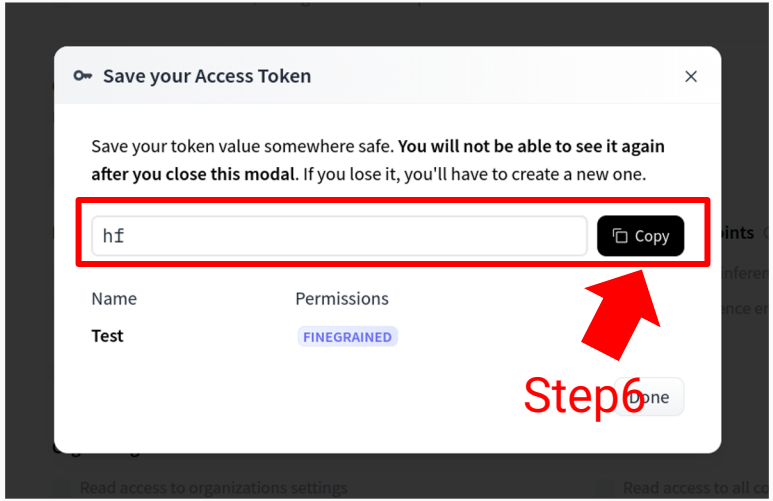


Step5
Type a name here
(Can be arbitrary)



Step6

Connect to Huggingface (4/4)



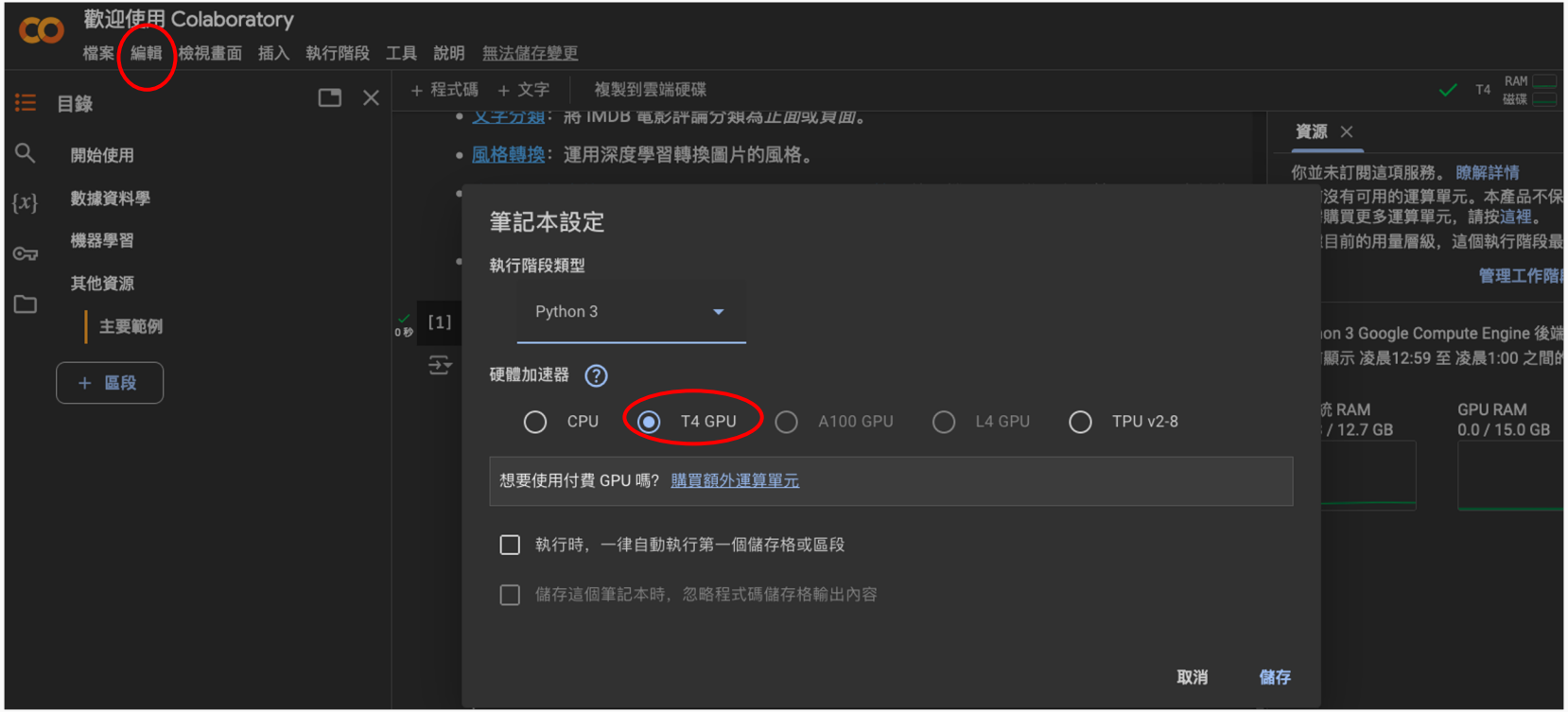

```
1  from huggingface_hub import login
2
3  hf_token = "                                    "
4  login(token=hf_token, add_to_git_credential=True)
```

```
[6]  1  !huggingface-cli whoami
     ZhiQuanFeng
```

Step7
Your access token here

If you succeed, your Hugging Face ID will be displayed here.

How to use GPU on Colab?



Type in a code block: `!nvidia-smi`

TODO1: Set up the environment of Ollama (1/3)

Introduction to Ollama

- Ollama is a platform designed for running and managing large language models (LLMs) directly **on local devices**, providing a balance between performance, privacy, and control.
- There are also other tools support users to manage LLM on local devices and accelerate it like *vllm*, *Llamafile*, *GPT4ALL*...etc.

Launch colabxterm

```
[ ]  1 # TODO1-1: You should install colab-xterm and launch it.
     2 # Write your commands here.
```

```
[ ]  1 # TODO1-2: You should install Ollama.
     2 # You may need root privileges if you use a local machine instead of Colab.
```

Install the colab-xterm package and use “load_ext” to use it.

TODO1: Set up the environment of Ollama (2/3)

```
[ ]   1 %xterm
```

```
[ ]   1 # TODO1-3: Pull Llama3.2:1b via Ollama and start the Ollama service in the xterm
      2 # Write your commands in the xterm
```

Use “%xterm” and the followint command to the command line:

- curl -fsSL https://ollama.com/install.sh | sh
- Download Llama3.2-1b using pull command in Ollama
- ollama serve

A simple test of Ollama

Ollama testing

You can test your Ollama status with the following cells.

```
[ ]  1 # Setting up the model that this tutorial will use
     2 MODEL = "llama3.2:1b" # https://ollama.com/library/llama3.2:3b
     3 EMBED_MODEL = "jinaai/jina-embeddings-v2-base-en"
```

```
[ ]  1 # Initialize an instance of the Ollama model
     2 llm = Ollama(model=MODEL)
     3 # Invoke the model to generate responses
     4 response = llm.invoke("What is the capital of Taiwan?")
     5 print(response)
```

- Here we define the retrieval model and document reader model.
- We can perform a simple test for checking Ollama's status.
- The .invoke API is to input sequence to the model and obtain the outputs.

Define the retriever model

```
[ ]
1 # Create an embedding model
2 model_kwargs = {'trust_remote_code': True}
3 encode_kwargs = {'normalize_embeddings': False}
4 embeddings_model = HuggingFaceEmbeddings(
5     model_name=EMBED_MODEL,
6     model_kwargs=model_kwargs,
7     encode_kwargs=encode_kwargs
8 )
```

Build a simple document retriever using LangChain (HuggingFaceEmbeddings).

TODO2: Load the cat-facts dataset and prepare the retrieval database

```
[ ]  1 !wget https://huggingface.co/ngxson/demo_simple_rag_py/resolve/main/cat-facts.txt
```

```
[ ]  1 # TODO2-1: Load the cat-facts dataset (as `refs`, which is a list of strings for all the cat facts)
     2 # Write your code here
```

```
[ ]  1 from langchain_core.documents import Document
     2 docs = [Document(page_content=doc, metadata={"id": i}) for i, doc in enumerate(refs)]
```

Load the data to be retrieved and use the langchain.docstore.document.Document API to construct a database.

TODO2: Load the cat-facts dataset and prepare the retrieval database

```
[ ]
# TODO2-2: Prepare the retrieval database
# You should create a Chroma vector store.
# search_type can be “similarity” (default), “mmr”, or “similarity_score_threshold”
vector_store = Chroma.from_documents(
    # Write your code here
)
retriever = vector_store.as_retriever(
    # Write your code here
)
```

TODO3: Set up the `system_prompt` and configure the prompt

Prompt setting

```
[ ]  1 # TODO3: Set up the `system_prompt` and configure the prompt.
     2 system_prompt = # Write your code here
     3 prompt = ChatPromptTemplate.from_messages(
     4     [
     5         ("system", system_prompt),
     6         ("human", "{input}"),
     7     ]
     8 )
```

- For the vectorspace, the common algorithm would be used like Faiss, Chroma...(https://python.langchain.com/docs/integrations/vectorstores/) to deal with the extreme huge database.

Write a system prompt to guide the document reader model in performing the desired task.

TODO4: Build and run the RAG system

```
[ ]  1 # TODO4: Build and run the RAG system
     2 # TODO4-1: Load the QA chain
     3 # You should create a chain for passing a list of Documents to a model.
     4 question_answer_chain = # Write your code here
     5                        stuff_documents_chain
     6 # TODO4-2: Create retrieval chain
     7 # You should create retrieval chain that retrieves documents and then passes them on.
     8 chain = # Write your code here
     9        retrieval_chain
```

The Question and Answer Pairs

```
[1]  1 # Question (queries) and answer pairs
     2 # Please do not modify this cell.
     3 queries = [
     4     "How much of a day do cats spend sleeping on average?",
     5     "What is the technical term for a cat's hairball?",
     6     "What do scientists believe caused cats to lose their sweet tooth?",
     7     "What is the top speed a cat can travel over short distances?",
     8     "What is the name of the organ in a cat's mouth that helps it smell?",
     9     "Which wildcat is considered the ancestor of all domestic cats?",
    10     "What is the group term for cats?",
    11     "How many different sounds can cats make?",
    12     "What is the name of the first cat in space?",
    13     "How many toes does a cat have on its back paws?"
    14 ]
    15 answers = [
    16     "2/3",
    17     "Bezoar",
    18     "a mutation in a key taste receptor",
    19     ["31 mph", "49 km"],
    20     "Jacobson's organ",
    21     "the African Wild Cat",
    22     "clowder",
    23     "100",
    24     ["Felicette", "Astrocat"],
    25     "four",
    26 ]
```

The queries (the ten questions) and the correct answers are provided in the notebook file.

TODO4-3 and TODO5: Improve to let the LLM correctly answer the ten questions.

Input the query to the RAG system and get the response

```
[ ]
counts = 0
for i, query in enumerate(queries):
    # TODO4-3: Run the RAG system
    response = # Write your code here
    print(f"Query: {query}\nResponse: {response['answer']}\n")
    # The following lines perform evaluations.
    # if the answer shows up in your response, the response is considered correct.
    if type(answers[i]) == list:
        for answer in answers[i]:
            if answer.lower() in response['answer'].lower():
                counts += 1
                break
    else:
        if answers[i].lower() in response['answer'].lower():
            counts += 1

# TODO5: Improve to let the LLM correctly answer the ten questions.
print(f"Correct numbers: {counts}")
```

Evaluate the response

Submission

Scoring

Coding work : 60%

- (10%) TODO1: Set up the environment of Ollama
- (10%) TODO2: Load the cat-facts dataset and prepare the retrieval database
- (15%) TODO3: Set up the `system_prompt` and configure the prompt.
- (15%) TODO4: Build and run the RAG system
- (10%, 1% per question) TODO5: Improve to let the LLM correctly answer the ten questions.

Report: 40%

- (10%) Please describe the **details of your implementation for the RAG system** (please tell us 1. What's in your RAG system? 2. Which retrieval model you use? 3. What's your prompt? 4. What's new in your code in comparison with the code from our lab course?) in this assignment and **list your best score for the ten questions**.
- (10%) Please provide analysis for the RAG performance using different prompts.
- (10%) Please compare the RAG performance with different retrieval models and the performance without using RAG (note that Llama 3.2 should not be fine-tuned in this assignment).
- (10%) Anything that can strengthen your report.

Delivery policies: File formats

- Coding work: Python file (.py)
  - Download your script via Colab.
- Package list: requirements.txt
  - E.g., numpy==1.26.3
- Report: Microsoft Word (.docx)
- No other formats are allowed.
- Zip the files above before uploading you assignment.

Delivery policies: Filenames

- Do not forget the correct formats!

	Filename rule	**Filename example**
Coding work	NLP_HW4_school_student_ID.py	NLP_HW4_NTHU_12345678.py
Report	NLP_HW4_school_student_ID.docx	NLP_HW4_NTHU_12345678.docx
Package list	requirements.txt	
Zipped file	NLP_HW4_school_student_ID.zip	NLP_HW4_NTHU_12345678.zip

Delivery policies: Things You should include

- In your report:

	Example	
Environment types	**If Colab or Kaggle**	**If local**
Running environment	Colab	System: Ubuntu 22.04, CPU: Ryzen 7-7800X3D
Python version	Colab	Python 3.10.1

Delivery policies: Rules of coding

- If you use ChatGPT or Generative AI, please specify your usage **both** in:
  - **Code comments**
  - **Reports**
- **No plagiarism**. You should not copy and paste from your classmates. **Submit duplicate code or report will get 0 point !**
- Please provide links if you take the code from the Internet as reference.
- The following behaviors will cause loss in the score of the assignment: **(1) Usage with Generative AI without specifications (2) Internet sources without specifications (3) Plagiarism.**

Uploading the zipped file

- Please upload your file to NTU COOL.
- Typically, you will have at most three weeks to finish this assignment.
- If you have any question, please e-mail to **nthuikmlab@gmail.com**
- For sending an email, please include **[NLP AS4]** in your email title.
    - Example email title: [NLP AS4] Question about the scoring

Punishments

Rules	Name your code as NLP_HW4_school_student_ID.py (only .py is allowed!)	Name your code as NLP_HW4_school_student_ID.docx (only .docx is allowed!)	Include `requirements.txt` in the folder	Zip your files into NLP_HW4_school_student_ID.zip (only .zip is allowed!)	Include the running envrionment in your report
Punishment	-5	-5	-5	-5	-5
Rules	Include the Python version in your report	Include the GPU card(s) you use in your report	Usage with GAI or Internet sources with proper specifications	Do not copy and paste the code from your classmates	
Punishment	-5	-5	-100	-100 (for both)	