CS4262/5462 Tutorial
LLM Finetuning & Alignment

TA: Noppanat Wadlom
Email: noppanat@u.nus.edu

Outline

01
LLM post-training

02
SFT with LoRA

03
Alignment with GRPO

04
Tutorial guidelines

05
Submission

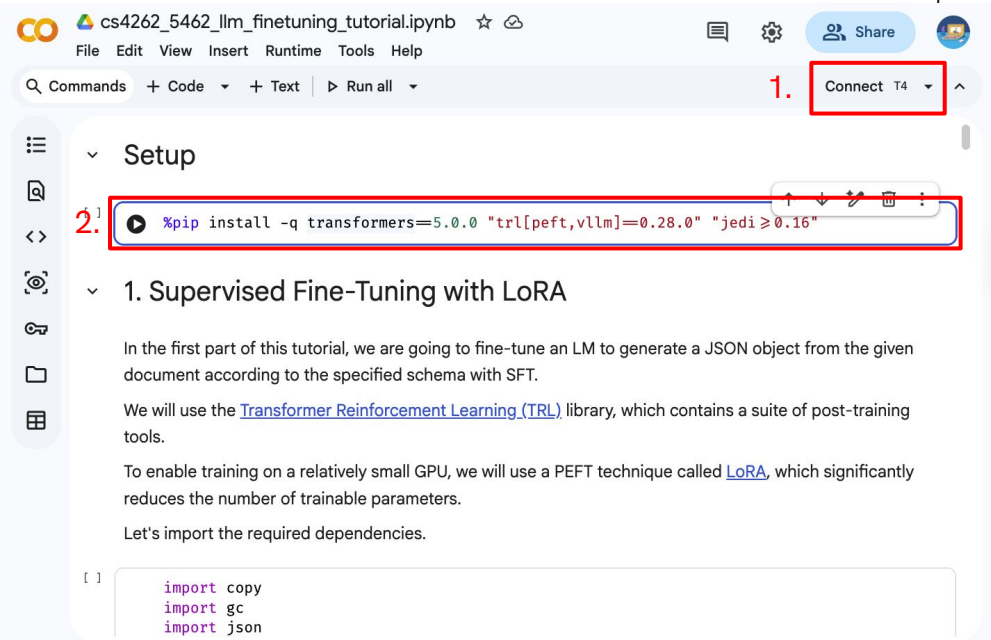
Tutorial Notebook

We will use **Google Colab** for this tutorial.

Link:
https://colab.research.google.com/drive/1XCGv9RR4Xaw3JOl0I_ZlrVirUW9EqMwF?usp=sharing

Make a copy, connect to the GPU runtime, and run the first few cells to set up.

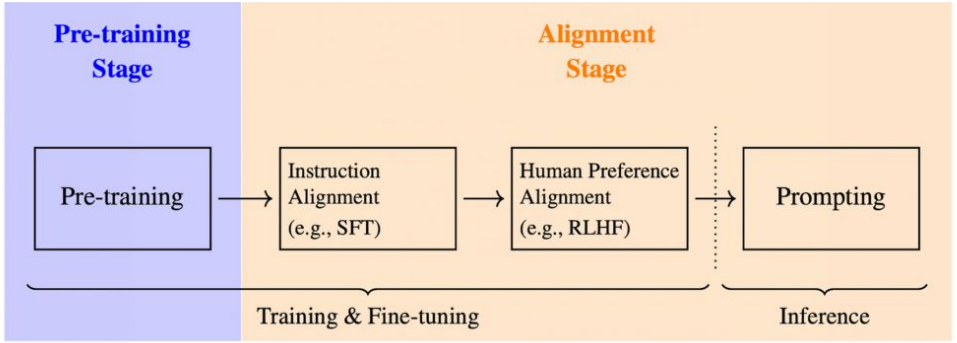
This may take a few minutes.



LLM Post-Training

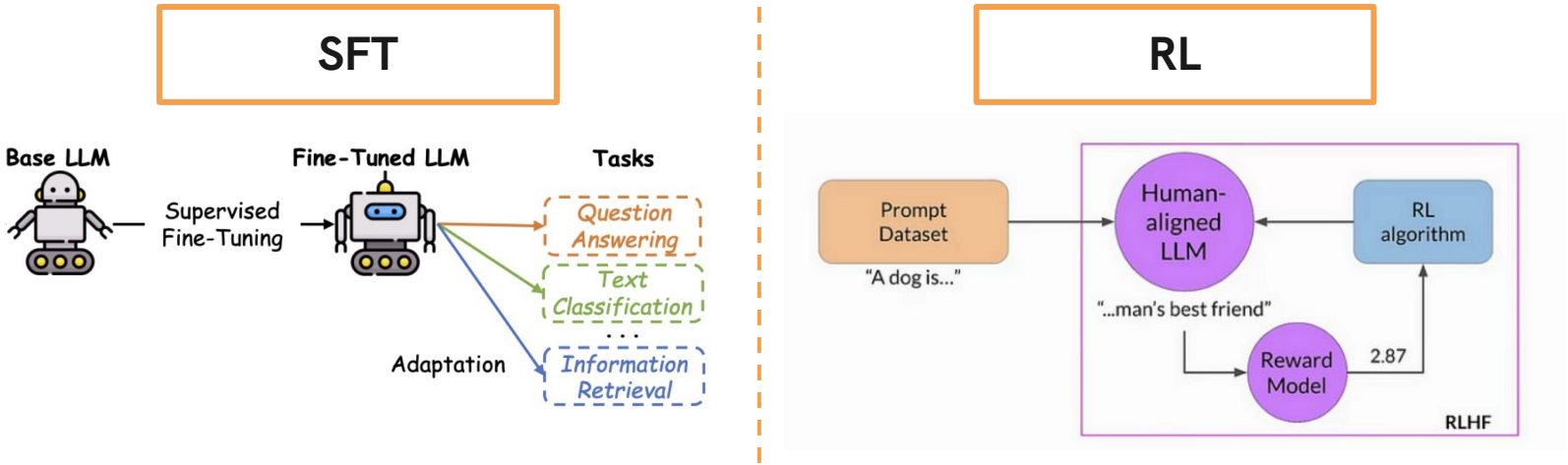
LLM training has two main stages.

- **Pre-training**:
  An LLM is trained on a massive dataset for language modeling.
- **Post-training:**
  - **Supervised Fine-Tuning (SFT)**
  - **Direct Preference Optimization (DPO)**
  - **Reinforcement Learning**, e.g., RLHF, RLAIF, PPO, **GRPO**



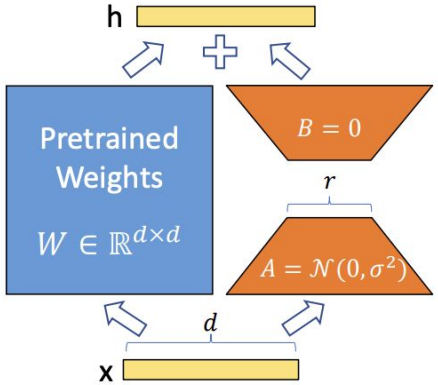
LLM Post-Training

- A pre-trained LLM acquire knowledge and language representation.
- **SFT** aligns the model with specific data, instructions, or output formats.
- **RL** and **DPO** aligns the model with human preferences, e.g., writing style.



SFT with LoRA

- SFT trains an LLM on a custom-labeled dataset to perform some downstream task.
- SFT involves **model weight updates**. ⇒ *very computationally intensive*
- **LoRA** to the rescue!



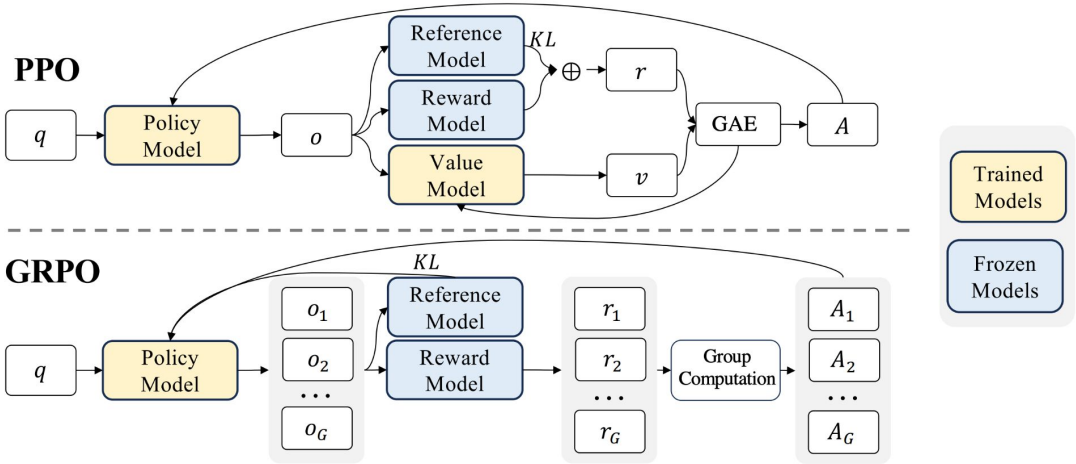
Low-Rank Adaptation (LoRA) is a **PEFT** technique that attaches the **adapter** (BA) of **rank *r*** to the LLM.

W: $d \times k$, B: $d \times r$, and A: $r \times k$, where $r \ll \min(d, k)$.

Key idea: LoRA only updates A and B during training ⇒ much less parameters compared to W.

Alignment with GRPO

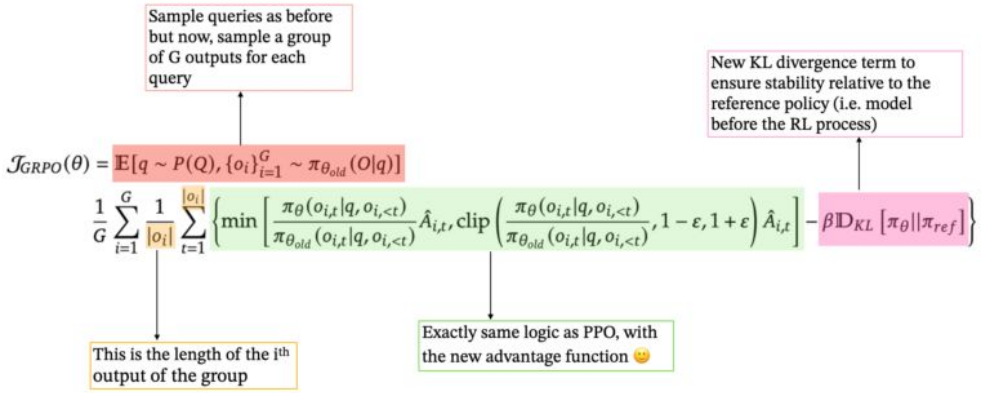
- Traditional RL like RLHF and PPO requires a **value model**, which is computationally expensive to run.
- **Group Relative Policy Optimization** (GRPO) replaces the value model with rule-based rewards.

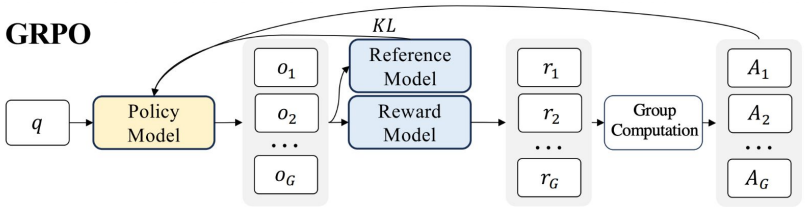


Alignment with GRPO

GRPO:

1. Sample multiple outputs from the model.
2. Calculate the reward for each output.
3. Optimize the model based on the group relative advantage.
4. Repeat.



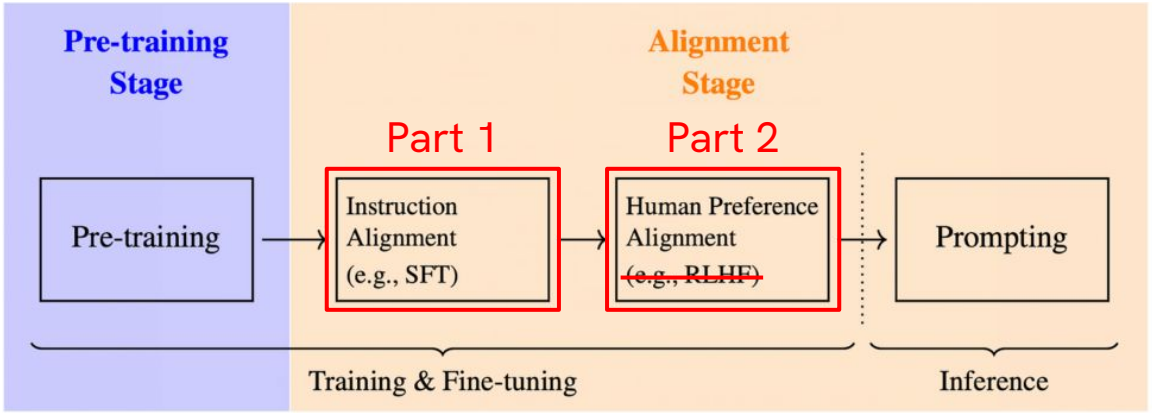


Tutorial Guidelines

In this tutorial, we are going to fine-tune an LM for JSON generation.

- **Part 1: SFT with LoRA**
- **Part 2: Alignment with GRPO**

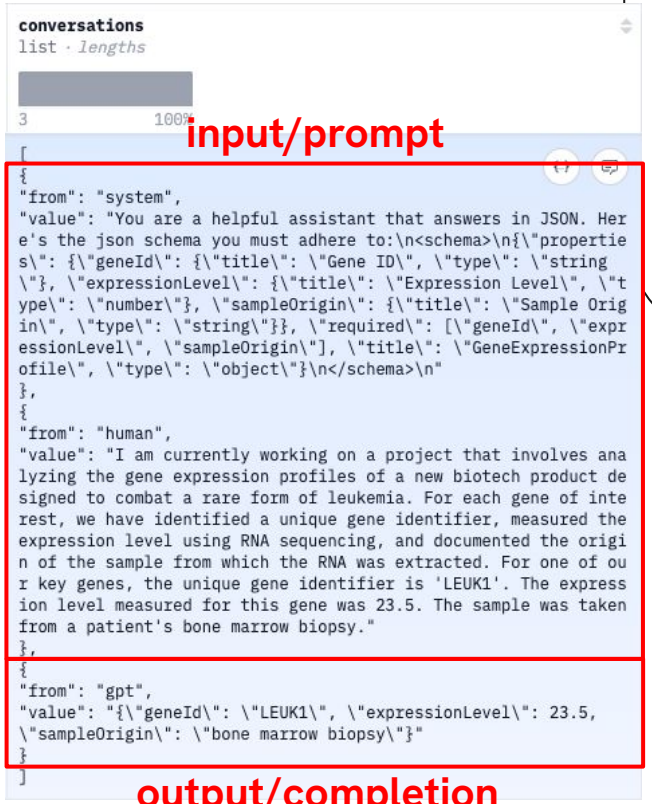
All details, TODO items, and hints can be found in the Colab notebook.



Tutorial Guidelines

Part 1: SFT with LoRA

- We are going to fine-tune a small LM (HuggingFaceTB/SmolLM-135M-Instruct) with LoRA on a **JSON generation task**.
- We will use the NousResearch/hermes-function-calling-v1 dataset, especially the json_mode_singleturn subset.



Tutorial Guidelines

Part 1: SFT with LoRA

- **(Task 1) 1.1.2 Transform dataset (10pt)**
  - The dataset is not in a useable format.
  - Transform the conversations column into the prompt and completion columns.

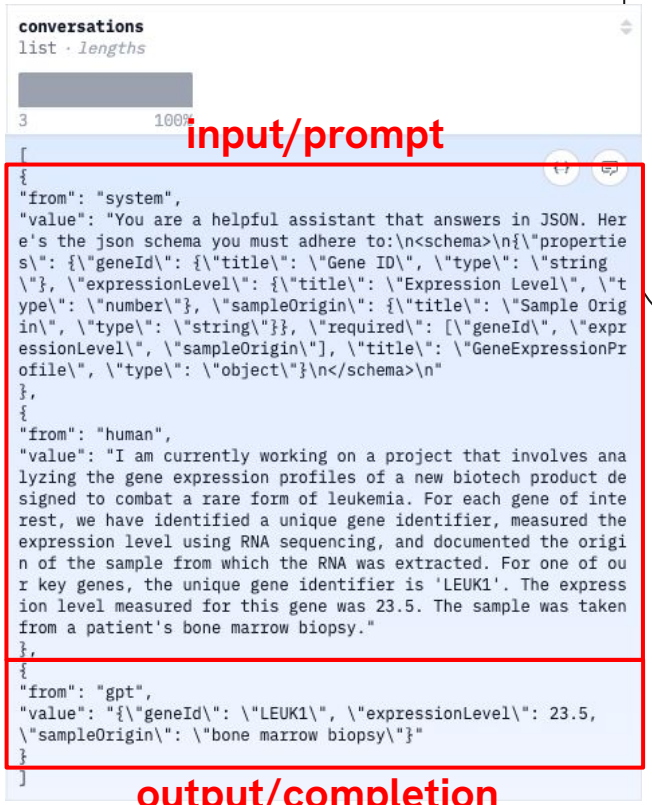
```python
def add_prompt_completion_columns(dataset: Dataset) -> Dataset:
    """Adds `prompt` and `completion` columns to the dataset by transforming the
    `conversations` column

    See the above description for the expected format of the `prompt` and `completion`
    columns.
    """
    # TODO: Add your code here
    # ═══ Start of your code ═══
    raise NotImplementedError
    # ═══ End of your code ═══


dataset = add_prompt_completion_columns(dataset)

# Check the required columns
assert "prompt" in dataset.column_names and "completion" in dataset.column_names

# Remove unnecessary columns
dataset = dataset.select_columns(["id", "prompt", "completion", "schema"])
```



Tutorial Guidelines

Part 1: SFT with LoRA

- **(Task 2) 1.3 SFT configurations**
  - Set the hyperparameters so that the model learn to generate JSON.
- **1.5 Evaluate SFT model (30pt)**

1. `json_parse_rate`
   - **10**: ≥ 0.7
   - **5**: ≥ 0.5 and < 0.7
   - **0**: < 0.5
2. `schema_f1`
   - **10**: ≥ 0.6
   - **5**: ≥ 0.4 and < 0.6
   - **0**: < 0.4
3. `content_f1`
   - **10**: ≥ 0.5
   - **5**: ≥ 0.3 and < 0.5
   - **0**: < 0.3

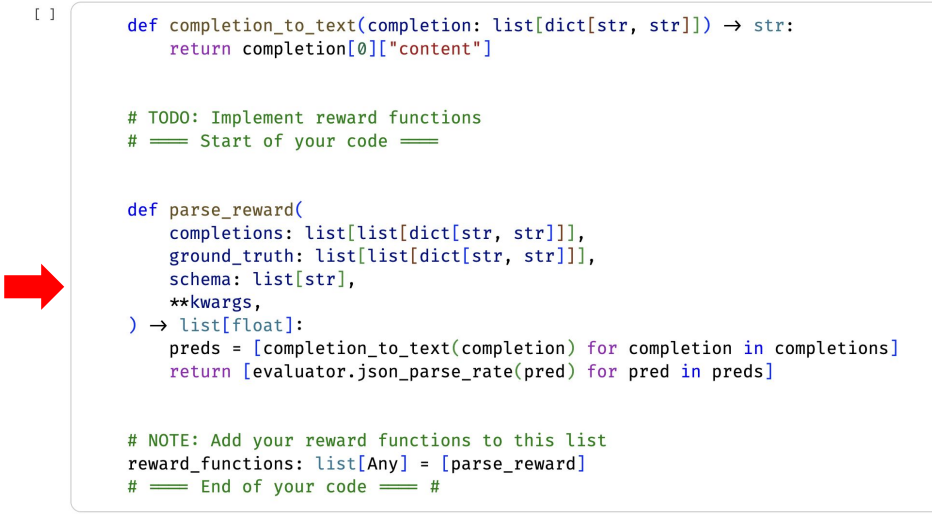
```
[ ]
# LoRA config
# TODO: Modify these hyperparameters
# ═══ Start of your code ═══
lora_r = 32
lora_alpha = 32
lora_dropout = 0.1
target_modules = ["q_proj", "v_proj", "k_proj"]
# ═══ End of your code ═══
```

```
[ ]
# SFT config
sft_model_name = "json-generation-lora-sft"
# TODO: Modify these hyperparameters
# ═══ Start of your code ═══
num_train_epochs = 1
max_steps = -1
per_device_train_batch_size = 16
# Hyperparameters
optim = "adamw_torch_fused" if device == "cuda" else "adamw_torch"
gradient_accumulation_steps = 1
learning_rate = 5e-4
weight_decay = 0.01
lr_scheduler_type = "cosine"
warmup_steps = 10
# Other training arguments
logging_steps = 5
eval_steps = logging_steps
save_steps = 0
eval_strategy = "steps"
# ═══ End of your code ═══
```

Tutorial Guidelines

Part 2: Alignment with GRPO

- **(Task 3) 2.2 Define reward functions (15pt)**
  - Implement *at least 3* ***non-trivial*** reward functions.



```
[ ]
def completion_to_text(completion: list[dict[str, str]]) → str:
    return completion[0]["content"]


# TODO: Implement reward functions
# ═══ Start of your code ═══


def parse_reward(
    completions: list[list[dict[str, str]]],
    ground_truth: list[list[dict[str, str]]],
    schema: list[str],
    **kwargs,
) → list[float]:
    preds = [completion_to_text(completion) for completion in completions]
    return [evaluator.json_parse_rate(pred) for pred in preds]


# NOTE: Add your reward functions to this list
reward_functions: list[Any] = [parse_reward]
# ═══ End of your code ═══ #
```

Tutorial Guidelines

Part 2: Alignment with GRPO

- **(Task 4) 2.3 GRPO configurations**
  - Set the hyperparameters to improve model performance.

```
[ ]
# GRPO config
grpo_model_name = "json-generation-lora-grpo"
# TODO: Modify these hyperparameters
# ═══ Start of your code ═══
num_train_epochs = 1
max_steps = -1
per_device_train_batch_size = 16  # Must be divisible by `num_generations`
num_generations = 4
# Hyperparameters
optim = "adamw_torch_fused" if device == "cuda" else "adamw_torch"
gradient_accumulation_steps = 1
learning_rate = 2e-5
weight_decay = 0.01
lr_scheduler_type = "cosine"
warmup_steps = 10
# Other training arguments
logging_steps = 5
save_steps = 0
# ═══ End of your code ═══
```

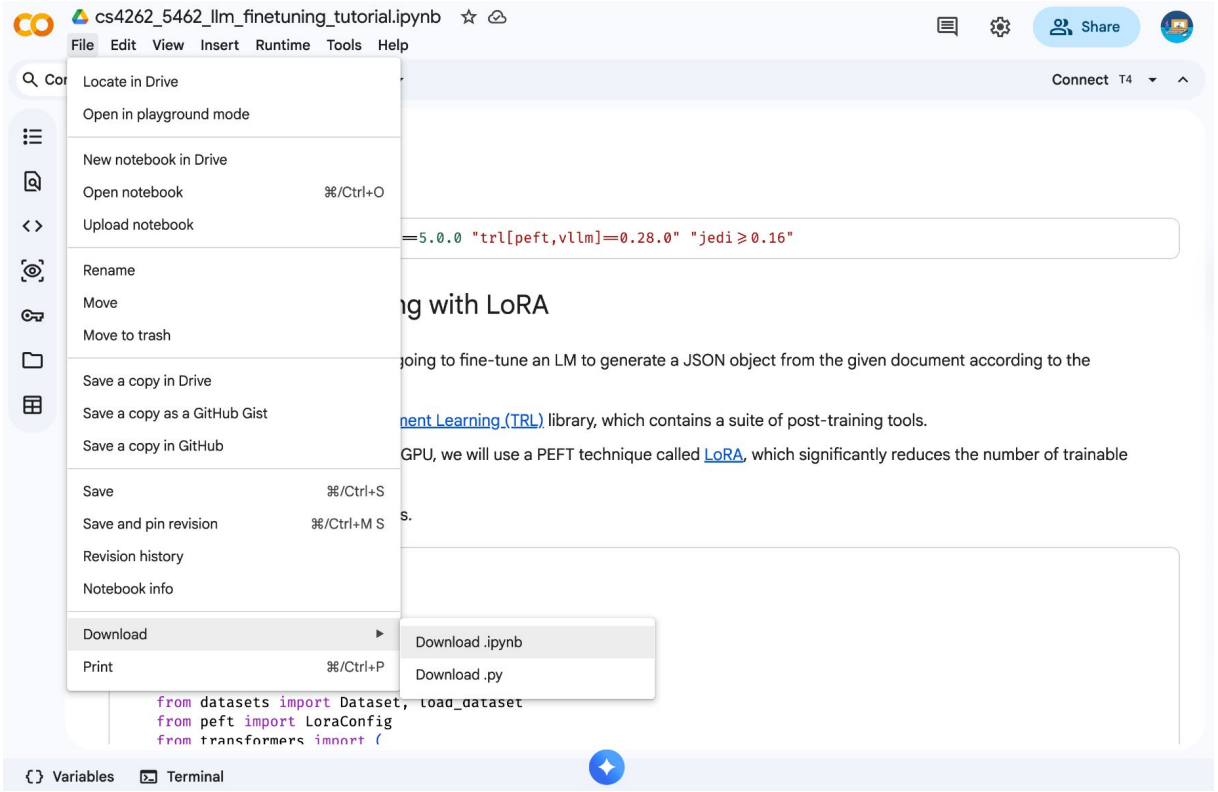
2.5 Evaluate GRPO model (45pt)

1. `json_parse_rate`
   - **15**: ≥ 0.8
   - **7.5**: ≥ 0.5 and < 0.8
   - **0**: < 0.5
2. `schema_f1`
   - **15**: ≥ 0.7
   - **7.5**: ≥ 0.4 and < 0.7
   - **0**: < 0.4
3. `content_f1`
   - **15**: ≥ 0.6
   - **7.5**: ≥ 0.3 and < 0.6
   - **0**: < 0.3

Submission

- Fill in four tasks.
  - 1.1.2 Transform dataset (10pt)
  - 1.3 SFT configurations ⇒ 1.5 Evaluate SFT model (30pt)
  - 2.2 Define reward functions (15pt)
  - 2.3 GRPO configurations ⇒ 2.5 Evaluate GRPO model (45pt)
- Save and upload your notebook (as .ipynb) to Canvas.
  - You can add print statements or debugging code outside of the TODO parts, but do not change code functionality unless explicitly allowed.
  - Run the notebook and keep all cell outputs!!!

Submission


cs4262_5462_llm_finetuning_tutorial.ipynb
File Edit View Insert Runtime Tools Help
Share
Connect T4
Locate in Drive
Open in playground mode
New notebook in Drive
Open notebook ⌘/Ctrl+O
Upload notebook
Rename
Move
Move to trash
Save a copy in Drive
Save a copy as a GitHub Gist
Save a copy in GitHub
Save ⌘/Ctrl+S
Save and pin revision ⌘/Ctrl+M S
Revision history
Notebook info
Download
Print ⌘/Ctrl+P
Download .ipynb
Download .py
=5.0.0 "trl[peft,vllm]==0.28.0" "jedi≥0.16"
ng with LoRA
going to fine-tune an LM to generate a JSON object from the given document according to the
nent Learning (TRL) library, which contains a suite of post-training tools.
GPU, we will use a PEFT technique called LoRA, which significantly reduces the number of trainable
s.
from datasets import Dataset, load_dataset
from peft import LoraConfig
from transformers import (
Variables
Terminal

References

- GRPO tutorial: https://towardsdatascience.com/training-large-language-models-from-trpo-to-grpo/
- Survey of LLM post-training: https://arxiv.org/abs/2503.06072
- LoRA: https://arxiv.org/pdf/2106.09685
- GRPO: https://arxiv.org/abs/2402.03300
- Dataset: https://huggingface.co/datasets/NousResearch/hermes-function-calling-v1
- Model: https://huggingface.co/HuggingFaceTB/SmolLM-135M-Instruct

THANK YOU