Machine Learning HW7

BERT - Question Answering

ML TAs
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Outline

1. Task Introduction
2. Grading
3. Tutorial
4. Hints
5. Regulations

Colab Link:
[Link]

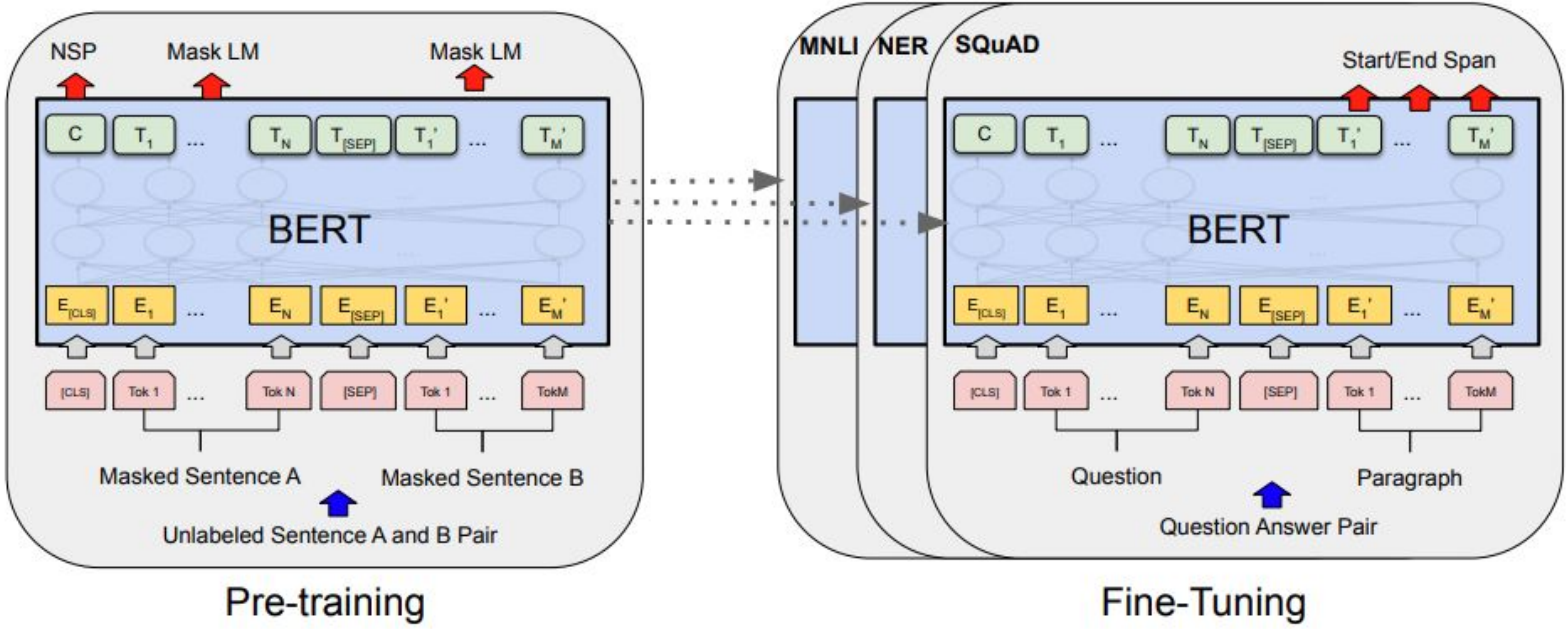
Kaggle Link:
www.kaggle.com/c/ml2021-spring-hw7

Video Link:
(English) (Chinese)

Deadline:
Kaggle: 2021/5/21 23:59
Code and Report: 2021/5/23 23:59
No Late Submission!

1. Task Introduction

BERT



https://arxiv.org/abs/1810.04805

Task: Extractive Question Answering

- Extraction-based Question Answering (QA) (E.g. SQuAD)

Document: $D = \{d_1, d_2, \cdots, d_N\}$

Query: $Q = \{q_1, q_2, \cdots, q_N\}$

output: two integers (s, e)

Answer: $A = \{q_s, \cdots, q_e\}$

In meteorology, precipitation is any product of the condensation of 17 spheric water vapor that falls under gravity. The main forms of precipitation include drizzle, rain, sleet, snow, graupel and hail... Precipitation forms as smaller droplets coalesce via collision with other rain drops or ice crystals within a cloud. Short, intense periods of rain 77 atte 79 cations are called "showers".

What causes precipitation to fall?
gravity $s = 17, e = 17$

What is another main form of precipitation besides drizzle, rain, snow, sleet and hail?
graupel

Where do water droplets collide with ice crystals to form precipitation?
within a cloud $s = 77, e = 79$

https://speech.ee.ntu.edu.tw/~hylee/ml/ml2021-course-data/bert_v8.pdf#page=23

Dataset: Chinese Reading Comprehension


```
{
    "questions": [
        {
            "id": 0,
            "paragraph_id": 3884,
            "question_text": "羅馬教皇利奧三世在800年正式加冕誰為羅馬
            "answer_text": "查理大帝",
            "answer_start": 141,
            "answer_end": 144
        },
        {
            "id": 1,
            "paragraph_id": 4630,
            "question_text": "百濟國在哪一年建國?",
            "answer_text": "公元前18年",
            "answer_start": 266,
            "answer_end": 271
```

```
"paragraphs": [
    "2010年引進的廣州快速公交運輸系統，屬世界第二大快速公交系統，日常載
    "廣州是京廣鐵路、廣深鐵路、廣茂鐵路、廣梅汕鐵路的終點站。2009年末，
    "廣州自古已是華南地區著名的商埠，擁有2000多年的開放貿易歷史。1970
    "廣州市內雨水充潤、土地肥沃，市區曾經有非常廣大的農業用地。兩千年前
    "古代廣州的手工業非常發達，船舶業、冶鑄和五金業、紡織業、食品加工、
    "中華人民共和國成立後工業國有化。五六十年代時，工業有所恢復，但文化
```


Testing: No answer!


```
"questions": [
    {
        "id": 0,
        "paragraph_id": 792,
        "question_text": "士官長的頭盔上會有何裝飾物?",
        "answer_text": null,
        "answer_start": null,
        "answer_end": null
```

Dataset: Chinese Reading Comprehension

Paragraph

新加坡、馬來西亞的華文學術界在 **1970**年代後開始統一使用簡體中文；然而 **繁體字**在媒體中普遍存在著，例如華人商店的招牌、舊告示及許多非學術類中文書籍，香港和臺灣所出版的書籍也有在市場上流動。當地許多中文報章都會使用「標題繁體字，內容簡化字」的方式讓簡繁中文並存。除此之外，馬來西亞所有本地中文報章之官方網站都是以繁體中文為主要文字。

Question: 新加坡的華文學術界在哪個年代後開始使用簡體中文 ？

Answer: **1970**

Question: 馬來西亞的華人商店招牌主要使用什麼文字 ？

Answer: **繁體字**

	# of Paragraphs	# of Questions
Training Set	~8000	~27000
Dev Set	~1000	~3500
Test Set	~1000	~3500

2. Grading

Grading

Upload Code to NTU COOL	+4pts
Simple Baseline (Public)	+1pt
Simple Baseline (Private)	+1pt
Medium Baseline (Public)	+1pt
Medium Baseline (Private)	+1pt
Strong Baseline (Public)	+0.5pt
Strong Baseline (Private)	+0.5pt
Boss Baseline (Public)	+0.5pt
Boss Baseline (Private)	+0.5pt
Report Bonus	+0.5pt

Kaggle (6pts)

Kaggle Link:
www.kaggle.com/c/ml2021-spring-hw7

Deadline: **5/21 (Fri.) 23:59**

Displayed name: <student ID>_<anything>

Testing Set: 3493 Questions (~50% public set, ~50% private set)

Evaluation Metric: Accuracy (Exact Match)

Baselines	Public Score
Simple (1pt + 1pt)	0.44622
Medium (1pt + 1pt)	0.68421
Strong (0.5pt + 0.5pt)	0.79290
Boss (0.5pt + 0.5pt)	0.84897

Submission Format: (csv)

Code Submission (4pts)

- **NTU COOL**
  - **Deadline: 5/23 (Sun.) 23:59**
  - Compress your code and report into **<student ID>_hw7.zip**(e.g. b10901118_hw7.zip)
  - We can only see your last submission.
  - **Do not submit your model or dataset.**
  - If your code is not reasonable, your semester grade x 0.9.

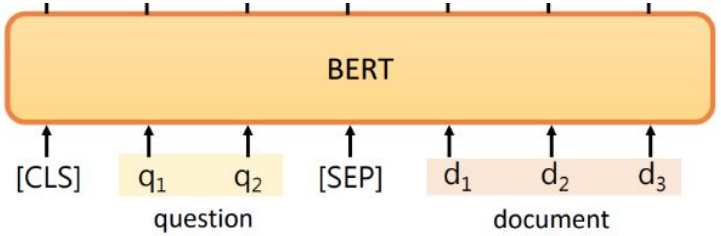
- Your .zip file should include only
  - **Code**: either .py or .ipynb
  - **Report**: .pdf (only for those who got 10 points)

Report template

3. Tutorial

A toy example

[Link to Demo]



Toy Example

文章: 李宏毅幾班大金。
題目: 李宏毅幾班？
答案: 大金

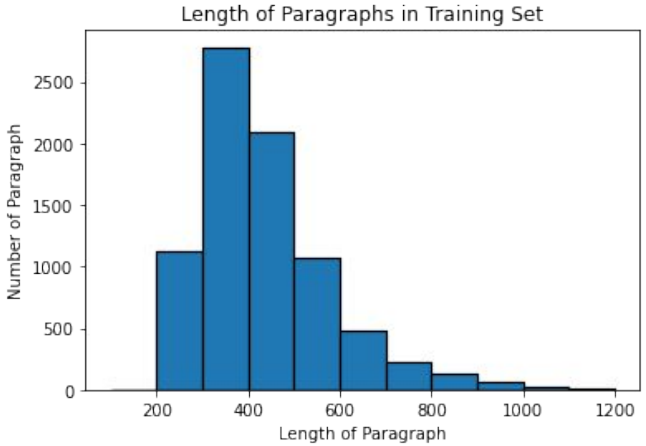
Paragraph: Jeanie likes Tom because Tom is good at deep learning.
Question: Why does Jeanie like Tom?
Answer: Tom is good at deep learning

Why Long Paragraph is an Issue?

Total sequence length = question length + paragraph length + 3 (special tokens)

Maximum input sequence length of BERT is restricted to 512, why?

➔ Self-Attention in transformer has $O(n^2)$ complexity



Therefore, we may not be able to process the whole paragraph.

What can we do?

Training

We know where the answer is in training!

Assumption: Info needed to answer the question can be found near the answer!

Simple solution: Just draw a window (as large as possible) around the answer!

e.g. window size = max_paragraph_len = 32

新加坡、馬來西亞的華文學術界在 **1970**年代後開始統一使用簡體中文；然而 **繁體字**在媒體中普遍存在著，例如華人商店的招牌、舊告示及許多非學術類中文書籍，香港和臺灣所出版的書籍也有在市場上流動 ...

Q: 新加坡的華文學術界在哪個年代後開始使用簡體中文 ？ **A:** **1970**

Q: 馬來西亞的華人商店招牌主要使用什麼文字 ？ **A:** **繁體字**

Testing

We do not know where the answer is in testing ⇨ split into windows!

e.g. window size = max_paragraph_len = 32

新加坡、馬來西亞的華文學術界在 **1970**年代後開始統一使用簡體中文；然而 **繁體字**在媒體中普遍存在著，例如華人商店的招牌、舊告示及許多非學術類中文書籍 .....

Q: 新加坡的華文學術界在哪個年代後開始使用簡體中文 ？ **A:** **1970**
Q: 馬來西亞的華人商店招牌主要使用什麼文字 ？ **A:** **繁體字**

For each window, model predicts a start score and an end score ⇨ take the maximum to be answer!

	start score	start position	end score	end position	total score
window 1	0.5	23	0.4	26	0.9
window 2	0.3	35	0.7	37	1.0

Answer:
position 35 to 37

4. Hints

Hints for beating baselines

- **Simple:**
  - Sample code
- **Medium:**
  - Apply linear learning rate decay
  - Change value of “doc_stride”
- **Strong:**
  - Improve preprocessing
  - Try other pretrained models
- **Boss:**
  - Improve postprocessing
  - Further improve the above hints

Estimated training time

	K80	T4	T4 (FP16)	V100
Simple	40m	20m	8m	7m
Medium	40m	20m	8m	7m
Strong	2h	1h	25m	20m
Boss	10h	5h	2h	1h30m

- **Training Tips (Optional):**
  - Automatic mixed precision (fp16)
  - Gradient accumulation
  - Ensemble

Linear Learning rate decay

```
##### TODO: Apply linear learning rate decay #####
```

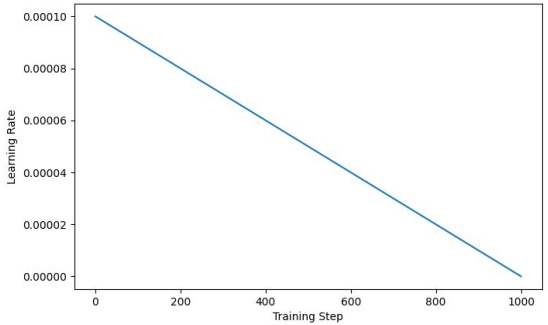
Method 1: Adjust learning rate manually

- Decrement **optimizer.param_groups[0]["lr"]** by **learning_rate / total training step** per step

```
learning_rate = 1e-4
optimizer = AdamW(model.parameters(), lr=learning_rate)
total_step = 1000
for i in range(total_step):
    optimizer.param_groups[0]["lr"] -= learning_rate / total_step
```

```
optimizer.param_groups[0]["lr"]
```

```
-1.5863074217500927e-18
```



Method 2: Adjust learning rate automatically by scheduler

- huggingface Link
- pytorch Link

```
scheduler = ...

for i in range(total_step):
    ...
    optimizer.step()
    scheduler.step()
    ...
```

You may also try other learning rate schedules (e.g. warmup)!

Doc stride

```
##### TODO: Change value of doc_stride #####
self.doc_stride = 150
```

Testing

We do not know where the answer is in testing ⇨ split into windows!

e.g. window size = max_paragraph_len = 32

新加坡、馬來西亞的華文學術界在**1970**年代後開始統一使用簡體中文；然而**繁體字**在媒體中普遍存在著，例如華人商店的招牌、舊告示及許多非學術類中文書籍.....

Q: 新加坡的華文學術界在哪個年代後開始使用簡體中文? **A:** **1970**

Q: 馬來西亞的華人商店招牌主要使用什麼文字? **A:** **繁體字**

start position of 2nd window

start position of 1st window

doc_stride = distance between the start position of two consecutive windows

doc_stride is set to “max_paragraph_len” in sample code (i.e. no overlap)

What if answer is near the boundary of windows or across windows?

Hint: Overlapping windows

Preprocessing

Hint: How to prevent model from learning something it should not learn during training? (i.e. answers are not always near the middle of window)

```
##### TODO: Preprocessing #####
# Hint: How to prevent model from learning something it should not learn

if self.split == "train":
        # Convert answer's start/end positions in paragraph_text to start/end positions in tokenized_paragraph
        answer_start_token = tokenized_paragraph.char_to_token(question["answer_start"])
        answer_end_token = tokenized_paragraph.char_to_token(question["answer_end"])

        # A single window is obtained by slicing the portion of paragraph containing the answer
        mid = (answer_start_token + answer_end_token) // 2
        paragraph_start = max(0, min(mid - self.max_paragraph_len // 2, len(tokenized_paragraph) - self.max_paragraph_len))
        paragraph_end = paragraph_start + self.max_paragraph_len

        # Slice question/paragraph and add special tokens (101: CLS, 102: SEP)
        input_ids_question = [101] + tokenized_question.ids[:self.max_question_len] + [102]
        input_ids_paragraph = tokenized_paragraph.ids[paragraph_start : paragraph_end] + [102]
```

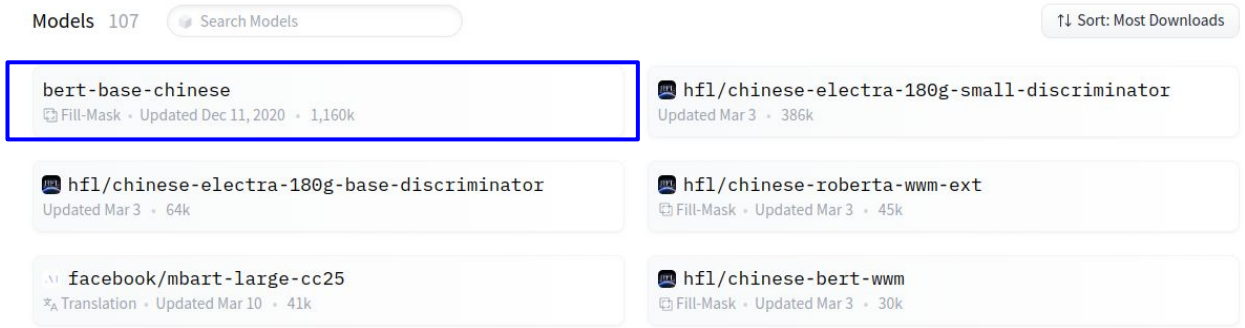
Other pretrained models

You can choose any model you like! [Link to pretrained models in huggingface]

Note 1: You are **NOT** allowed to use pretrained models outside huggingface! (Violation = cheating = final grade x 0.9)

Note 2: Some models have Model card describing details of the model

Note 3: Changing models may lead to error message, try it solve it yourself



Postprocessing

Hint: Open your prediction file to see what is wrong

(e.g. what if predicted end_index < predicted start_index?)

```
def evaluate(data, output):
    ##### TODO: Postprocessing #####
    # There is a bug and room for improvement in postprocessing
    # Hint: Open your prediction file to see what is wrong

    answer = ''
    max_prob = float('-inf')
    num_of_windows = data[0].shape[1]

    for k in range(num_of_windows):
        # Obtain answer by choosing the most probable start position / end position
        start_prob, start_index = torch.max(output.start_logits[k], dim=0)
        end_prob, end_index = torch.max(output.end_logits[k], dim=0)

        # Probability of answer is calculated as sum of start_prob and end_prob
        prob = start_prob + end_prob

        # Replace answer if calculated probability is larger than previous windows
        if prob > max_prob:
            max_prob = prob
            # Convert tokens to chars (e.g. [1920, 7032] --> "大 金")
            answer = tokenizer.decode(data[0][0][k][start_index : end_index + 1])

    # Remove spaces in answer (e.g. "大 金" --> "大金")
    return answer.replace(' ','')
```

Training Tip: Automatic mixed precision

- PyTorch trains with 32-bit floating point (FP32) arithmetic by default
- Automatic Mixed Precision (AMP) enables automatic conversion of certain GPU operations from FP32 precision to half-precision (FP16)
- Offer about 1.5-3.0x speed up while maintaining accuracy

```
# Change "fp16_training" to True to support mixed precision training (fp16)
fp16_training = False

if fp16_training:
    !pip install accelerate==0.2.0
    from accelerate import Accelerator
    accelerator = Accelerator(fp16=True)
# Documentation for the toolkit:  https://huggingface.co/docs/accelerate/
```

```
if fp16_training:
    model, optimizer, train_loader = accelerator.prepare(model, optimizer, train_loader)
```

```
if fp16_training:
    accelerator.backward(output.loss)
else:
    output.loss.backward()
```

Estimated training time

	T4	T4 (FP16)
Simple	20m	8m
Medium	20m	8m
Strong	1h	25m
Boss	5h	2h

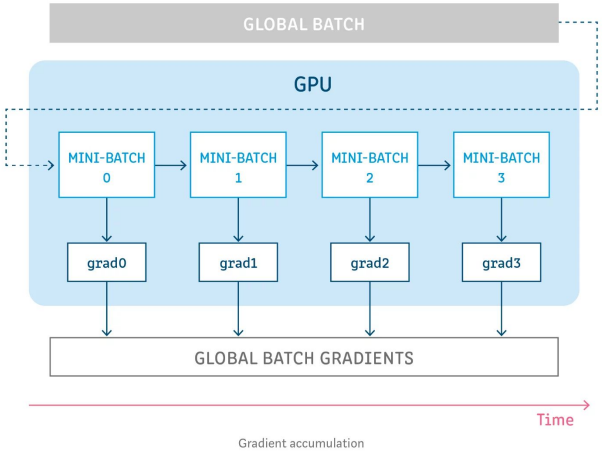
Warning: only work on some gpu (e.g. T4, V100)

Reference: accelerate documentation
Intro to native pytorch automatic mixed precision

Training Tip: Gradient accumulation

Use it when gpu memory is not enough but you want to use larger batch size

- Split global batch into smaller mini-batches
- For each mini-batch: Accumulate gradient without updating model parameters
- Update model parameters



Gradient accumulation

Reference: Gradient Accumulation in PyTorch

5. Regulations

Regulations

- You should NOT plagiarize, if you use any other resource, you should cite it in the reference. (*)
- You should NOT modify your prediction files manually.
- Do NOT share codes or prediction files with any living creatures.
- Do NOT use any approaches to submit your results more than 5 times a day.
- Do NOT search or use additional data.
- **Do NOT use any pre-trained models outside huggingface.**
- Your final grade x 0.9 if you violate any of the above rules.
- Prof. Lee & TAs preserve the rights to change the rules & grades.

(*) Academic Ethics Guidelines for Researchers by the Ministry of Science and Technology

If any questions, you can ask us via...

- NTU COOL (recommended)
  - https://cool.ntu.edu.tw/courses/4793
- Email
  - ntu-ml-2021spring-ta@googlegroups.com
  - The title **must** begin with “[hw7]”
- TA hours
  - Each Monday 19:00~21:00 @Room 101, EE2 (電機二館101)
  - Each Friday 13:30~14:20 Before Class @Lecture Hall (綜合大講堂)
  - Each Friday During Class