

BERT Sentiment Analysis to Detect Twitter Sarcasm (Naive Approach)

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A. Introduction

Sarcasm is a form of figurative language that implies a negative sentiment while displaying a positive sentiment on the surface (Joshi et al., 2017).

I present a *Naive* approach to detect *Twitter* tweet sarcasm sentiment using a transformers-based pre-trained model that considers only the *response tweet*. This approach completely ignores the *context* of the response tweet to train the model.

The model uses a transformer encoder to generate the embedding representation for the response. The model is trained and evaluated on the given training and testing datasets. My best performance model gives an *F1*-score of **75.79%**, *beating the Classification Competition baseline score after four epoch iterations (epoch # 4).*

“*C. Dataset Description*” section of this document explains further the *response* and *context* relationship.

Important files in the project:

1. Documented software code
 - Training and evaluation ([link](#))
 - Evaluation of a trained-model for demo purpose ([link](#))
2. Best performance testing set predictions (answer.txt) ([link](#))
3. Best performance trained-model ([link](#))
4. Training dataset ([link](#))
5. Testing dataset ([link](#))

B. Bidirectional Encoder Representations from Transformers (BERT)

This project uses BERT, a transformer-based technique for Natural Language Processing pre-training developed by a team in *Google*.

The original English language BERT model comes with two pre-trained model types:

| Model Type | Layer | Hidden | Head | Parameter | Corpus Word |
|--------------|-------|--------|------|-----------|-------------|
| Base | 12 | 768 | 12 | 110 M | 800 M |
| Large | 24 | 1024 | 16 | 340 M | 2.500 M |

Table 1: BERT original model types

BERT Large model essentially has better computing leverage than the base model. Google team trained the large model using a larger corpus word size than the base model. The large model is expected to perform better than the base model in most of the NLP tasks such as sentiment analysis.

Original BERT paper is available here ([link](#)).

C. Dataset Description

There are two *Twitter* tweet datasets available for this project:

1. Training dataset: a labeled dataset to train the model
2. Testing dataset: tweet with a unique ID to evaluate the trained-model

For the training dataset, each line contains a JSON object with the following columns:

- **label**: **SARCASM** or **NOT_SARCASM**
- **response**: the classified tweet
- **context**: the conversation context of the response

For the testing/evaluation dataset, each line contains a JSON object with the following columns:

- **id**: unique identifier for the sample
- **response**: the tweet to be classified
- **context**: the conversation context of the response

| Training Dataset | Testing Dataset |
|------------------|-----------------|
| 5000 lines | 1800 lines |

Table 2: Dataset size statistics

A more detailed dataset description is available in the project competition Github repository ([link](#)).

D. The Naive Approach

I hypothesize the **context** does not **always** support the sentiment of a **response**. Context can have an opposing effect on the sentiment of a response.

I hypothesize there are 2 types of context:

1. A **Positive context** is a context that supports the sentiment of a response.
2. A **Negative context** is a context that does not support the sentiment of a response.

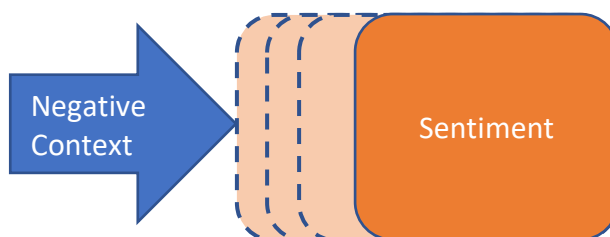


Fig.1: Illustration of context reduces sentiment quality

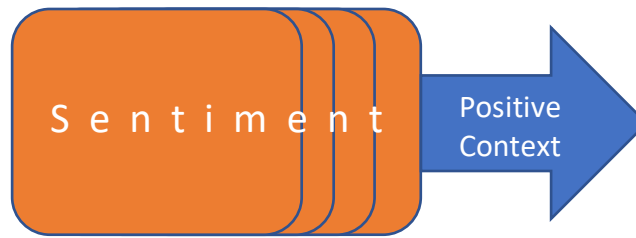


Fig.2: Illustration of context increase sentiment quality

It is critical to utilize the context to support the response's sentiment. For this project, I consider only the *sentiment-labeled* response to training the model, and I completely ignore the context. I call this a *Naive* approach.

In the future project, I can use advanced machine learning techniques to utilize response and context to train the model by *selectively reconstruct* the context to support the sentiment of a response.

E. The Model, Training, and Evaluation

In this project, I use the datasets to train and evaluate BERT Large uncased and base uncased models.

I use the original BERT paper as a reference ([A.3 Fine-tuning Procedure](#)) to choose hyperparameters for my experiments. The hyperparameters in my experiments are:

- Learning rate: $2e-5$
- Batch size: 5 (considering memory size)
- Epochs: 4 iterations
- Epsilon: $1e-8$
- Random seed value: 17

BERT model can handle a text with a maximum of 512 characters. If the input text is more than 512 characters, the model truncates the text to 512 characters.

Response text in training and testing datasets is less than 512 characters, in this case, we are guaranteed to consider all words in the response text to train and evaluate the model. The Python source code below prints the response maximum characters for training and testing datasets.

```
import pandas as pd
import json

with open('sample_data/train.jsonl') as f:
    lines_train = f.read().splitlines()
with open('sample_data/test.jsonl') as f:
    lines_test = f.read().splitlines()

df_train = pd.json_normalize(pd.DataFrame(lines_train)[0].apply(json.loads))
df_test = pd.json_normalize(pd.DataFrame(lines_test)[0].apply(json.loads))

print(f'Maximum train-response characters length: {df_train.response.str.len().max()}')
print(f'Maximum test-response characters length: {df_test.response.str.len().max()}')
```

Maximum train-response characters length: 315
Maximum test-response characters length: 310

Fig.3: Source code to check maximum training and evaluation response characters length

| | Response Max. Chars |
|------------------|---------------------|
| Training Dataset | 315 |
| Testing Dataset | 310 |

Table 3: Maximum response characters length

F. The Software Code

For the software code of this project, I implemented two Google Colab Notebooks:

1. **NAIVE_BERT_sentiment_analysis.ipynb**: Training and evaluation notebook ([link](#))
2. **DEMO_Model_Evaluation.ipynb**: Evaluation of selected trained-model notebook (for DEMO purpose) ([link](#))

I use the *Google Colab PRO* environment to implement and test the software code. Introduction about Google Colab is available here [link](#).

Software code uses the following main Python libraries:

- **Numpy** 1.18.5
- **Pytorch** 1.7.0+cu101
- **Huggingface Transformers** 3.5.0

F.1. NAIVE_BERT_sentiment_analysis.ipynb Code Review

This notebook trains and evaluates the BERT Large uncased and base uncased models using the provided datasets. In the end, the trained-model and evaluation results are copied and stored in the project Google Drive folder.

1. Colab Configuration

- a. Install Python modules required for the notebook.

```
!pip install transformers
!pip install PyDrive
```

b. Copy train.jsonl and test.jsonl files from Google Drive to Colab session

I have already copied train.jsonl and test.jsonl files to a Google Drive account created for this project. The files are shared with the public. The following code will copy the files from Google Drive to the Colab session.

```
# train.json file location: https://drive.google.com/file/d/1d51waHPOUBAz7c-cNXXQeFn75ZV2HkUh/view?usp=sharing
# test.jsonl file location: https://drive.google.com/file/d/1vA3uyqylTZmahgZ0PeNRFx67LuYeAkoW/view?usp=sharing

#####
# The training dataset #
#####
# Google Drive file name
training_file = 'train.jsonl'
# Google Drive unique file ID
training_file_id = '1d51waHPOUBAz7c-cNXXQeFn75ZV2HkUh'

#####
# The evaluation/testing dataset #
#####
# Google Drive file name
evaluation_file = 'test.jsonl'
# Google Drive unique file ID
test_jsonl_file_id = "1vA3uyqylTZmahgZ0PeNRFx67LuYeAkoW"

# The files are available to public in my Google Drive
# created for this project.
#
# Login using Google Account to proceed.
#
# Follow the link, copy-paste the code.

auth.authenticate_user()
gauth = GoogleAuth()
gauth.credentials = GoogleCredentials.get_application_default()
drive = GoogleDrive(gauth)

downloaded = drive.CreateFile({'id':training_file_id})
downloaded.GetContentFile(training_file)

downloaded = drive.CreateFile({'id':test_jsonl_file_id})
downloaded.GetContentFile(evaluation_file)
```

The source code above will prompt a URL. Click the URL, it will prompt the Google account login page.

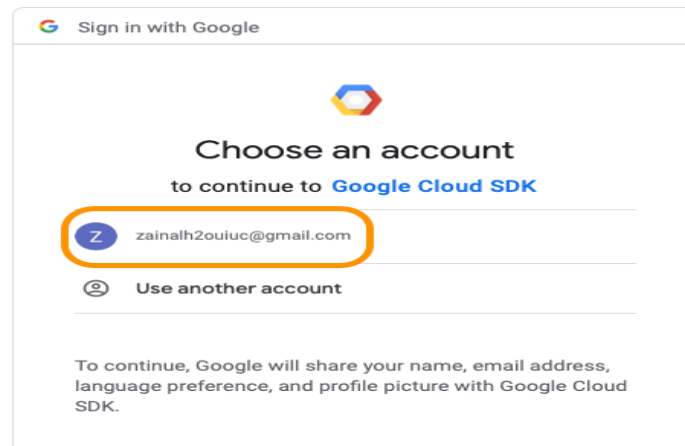
```
downloaded = drive.CreateFile({'id':test_jsonl_file_id})
downloaded.GetContentFile(evaluation_file)
```

Go to the following link in your browser:

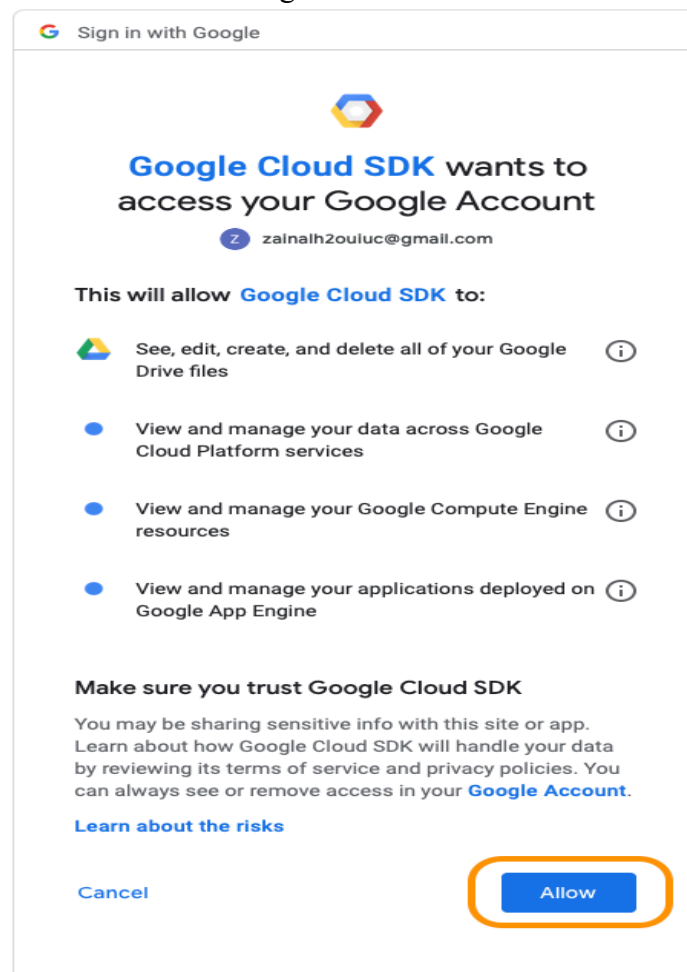
https://accounts.google.com/o/oauth2/auth?client_id=32555940559.apps.googleusercontent.com&redirect_uri=urn%3Aietf%3Awg%3Aoauth%3A2.0%3Aaoot

Enter verification code:

Select the Google account to run the notebook:



Click the “Allow” button to allow Google Cloud SDK to access the Google account.



That finally prompts the verification code. Copy the code and paste it in the “Enter verification code” text box. Press “Enter”



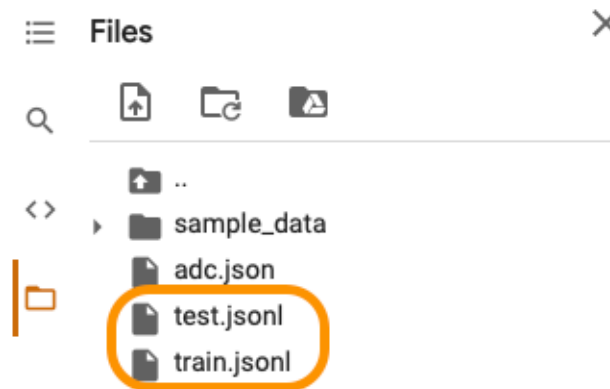
Sign in

Please copy this code, switch to your application and paste it there:

4/6AGF_kug7Ka8d68msDARK0VKPZNs1AZs8b1iZdry2
GsUDtfcK30ZuF8

Enter verification code: b1iZdry2GsUDtfcK30ZuF8

That will copy the training and testing datasets to the Colab session! We are ready to train and evaluate the model using the datasets.



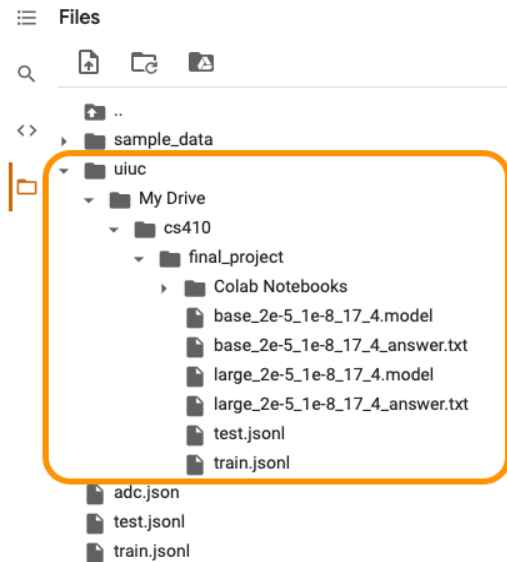
2. Mounting Google Drive to Colab session (To save result files)

To save the result files (the trained-model and answer.txt) to Google Drive, we need to mount Google Drive to the Colab session. In this project, I mount the Google Drive directory to the './content/uiuc' folder.

```
# Mount Google Drive to the current Colab session
# The trained model and answer file are copied to
# the Google Drive.
from google.colab import drive
drive.mount('/content/uiuc')
```

Mounted at /content/uiuc

At the end of this notebook code execution, the Google Drive mounted folder in the Colab session will look like the following:



Mounted Google Drive in Colab Session where to keep result files permanently

3. The Main Python Class

This project implements a Python class, `BERT_Model`, that handles the following tasks:

- Read the dataset from JSONL files into a list of JSON
- Convert list of JSON to Pandas DataFrame
- Create the BERT Model
- Run the training and save the model for each epoch
- Evaluate the model and store the result into a file

Below are the class signatures:

```
▶ class BERT_Model:
    # Class Initialization (set the hyperparameters here)
    def __init__(self):
        # Read train.jsonl or test.jsonl
        # and store it to Pandas DataFrame
    def read_dataset_file(self, the_file):
        # We create BERT model here
    def create_bert_model(self, df, lr, eps):
        # Training the model using train.jsonl
    def run_training(self, file_save, seed_val=17):
        # Evaluate the trained-model using test.jsonl
    def evaluate_model(self, file_name, df):
        # Write the evaluation result to answer.txt
        # We will publish answer.txt to LiveDataLab
        # for F1, Precision and Recall score evaluation!
    def write_answers(self, file_name, preds_flat):
```

For details please check the source code here [link](#). The source code comment describes what each step does.

The main algorithm of the training:

1. Create a BERT tokenizer. We use the tokenizer to encode the text and prepare the dataset.

```
encoded_data = self.tokenizer.batch_encode_plus(
    df.response.values,
    add_special_tokens=True,
    return_attention_mask=True,
    max_length=df.response.str.len().max()+5,
    padding='max_length',
    return_tensors='pt'
)

self.training_dataset = TensorDataset(encoded_data['input_ids'],
                                       encoded_data['attention_mask'],
                                       torch.tensor(df.label_value.values))
```

2. Create a BERT model using the chosen hyperparameter.

```
self.model = BertForSequenceClassification.from_pretrained(self.model_name,
                                                           num_labels=len(self.label_dict),
                                                           output_attentions=False,
                                                           output_hidden_states=False)

self.model.to(self.device)
```

3. Create AdamW optimizer ([link](#)), it is used to calculate the convergence in the model. It is considered the fastest convergence algorithm.

```
self.optimizer = AdamW(self.model.parameters(), lr=lr, eps=eps)
```

4. Create a data loader. The data loader main task is passing dataset batch to model. It will make sure all the text in the dataset is processed by the model.

```
data_loader = DataLoader(self.training_dataset, sampler=RandomSampler(self.training_dataset), batch_size=self.batch_size)
```

5. Set the model to train mode. Iterate the data loader to pass the dataset batch to the model until the training is completed.

```
# To set the model into a training mode.  
self.model.train()
```

```
# This is the actual learning.  
outputs = self.model(**inputs)
```

6. After the training is completed, save the trained model to a file.

```
# Save the trained BERT model for the current epoch iteration  
torch.save(self.model.state_dict(), f'{file_save}_{epoch+1}.model')
```

The main algorithm of testing:

1. Load the model file to the memory and set the model to evaluation mode.

```
self.model.load_state_dict(torch.load(file_name, map_location=torch.device(self.device)))  
self.model.eval()
```

2. Create the tokenizer, encode the input data for testing, and prepare the dataset.

```
encoded_data = self.tokenizer.batch_encode_plus(  
    df.response.values,  
    add_special_tokens=True,  
    return_attention_mask=True,  
    max_length=df.response.str.len().max()+5,  
    padding='max_length',  
    return_tensors='pt'  
)  
  
dataset = TensorDataset(encoded_data['input_ids'], encoded_data['attention_mask'])
```

3. Create the data loader to handle the evaluation batch.

```
dataloader = DataLoader(dataset, sampler=SequentialSampler(dataset), batch_size=self.batch_size)
```

4. Run the evaluation. One of the most important outputs from the model is **logits**. In this project, **logits** is an array of two elements. The model is configured to have the first element of **logits** represents SARCASM, and the second element represents NOT_SARCASM.

```
# evaluate the validation dataset
output = self.model(**inputs)
logits = output[0]
# print(output)
logits = logits.detach().cpu().numpy()
```

5. We use the NumPy argmax function to return the index of the maximum value in logits.
 - If the maximum value is the first element, the function returns the index array of **0** (SARCASM)
 - If the maximum value is the second element, the function returns the index array of **1** (NOT_SARCASM)

```
preds_flat = np.argmax(predictions, axis=1).flatten()
```

6. The final step is to write the output to a file (answer.txt)

```
f = open(file_name, "w")
i = 1
for pred in enumerate(preds_flat):
    if pred[1] == 0:
        text = 'SARCASM'
    else:
        text = 'NOT_SARCASM'
    f.write('twitter_{0},{1}\n'.format(i, text))
    i = i + 1
f.close()
```

4. Training and Evaluation experiments

To test my *Naive* hypothesis, I run experiments with the same hyperparameters on two BERT models.

1. Experiment-1: BERT base uncased

```
the_model = BERT_Model()
the_model.model_name = 'bert-base-uncased'
epoch_to_evaluate = 4

the_model.df_train = the_model.read_dataset_file(training_file)
the_model.df_eval = the_model.read_dataset_file(evaluation_file)

the_model.create_bert_model(the_model.df_train, 2e-5, 1e-8)
the_model.run_training('base_2e-5_1e-8_17', 17)
preds_flat = the_model.evaluate_model(f'base_2e-5_1e-8_17_{epoch_to_evaluate}.model', the_model.df_eval)
the_model.write_answers(f'base_2e-5_1e-8_17_{epoch_to_evaluate}_answer.txt', preds_flat)
```

2. Experiment-2: BERT LARGE uncased

```
the_model = BERT_Model()
the_model.model_name = 'bert-large-uncased'
epoch_to_evaluate = 4

the_model.df_train = the_model.read_dataset_file(training_file)
the_model.df_eval = the_model.read_dataset_file(evaluation_file)

the_model.create_bert_model(the_model.df_train, 2e-5, 1e-8)
the_model.run_training('large_2e-5_1e-8_17', 17)
preds_flat = the_model.evaluate_model(f'large_2e-5_1e-8_17_{epoch_to_evaluate}.model', the_model.df_eval)
the_model.write_answers(f'large_2e-5_1e-8_17_{epoch_to_evaluate}.answer.txt', preds_flat)
```

Both experiments code above will generate result files in the Colab session folder below:

The screenshot shows a Google Colab session titled "NAIVE BERT sentiment analysis.ipynb". The left sidebar displays a file explorer with a folder named "uiuc" containing several files. A box highlights the files: "base_2e-5_1e-8_17_1.model", "base_2e-5_1e-8_17_2.model", "base_2e-5_1e-8_17_3.model", "base_2e-5_1e-8_17_4.model", "base_2e-5_1e-8_17_4.answer.txt", "large_2e-5_1e-8_17_1.model", "large_2e-5_1e-8_17_2.model", "large_2e-5_1e-8_17_3.model", "large_2e-5_1e-8_17_4.model", and "large_2e-5_1e-8_17_4.answer.txt". The right pane shows a "7. Summary" section with two ranked results:

- Rank-1: BERT LARGE uncased**
 - F1 score: 0.757905138339921
 - Precision: 0.6823843416370107
 - Recall: 0.8522222222222222
- Rank-2: BERT BASE uncased**
 - F1 score: 0.7458777885548012
 - Precision: 0.6617900172117039
 - Recall: 0.8544444444444445

5. Save the result files to Google Drive

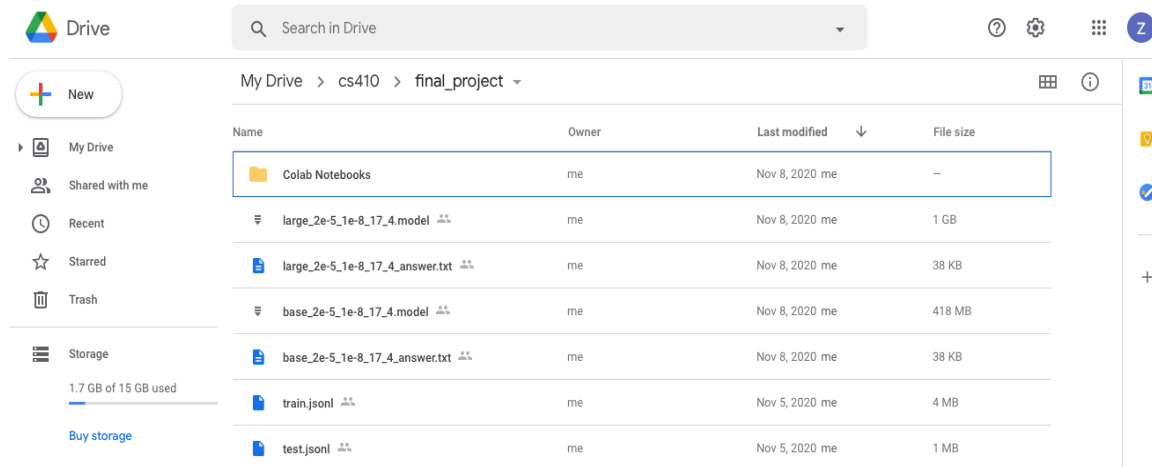
Colab deletes result files when the session ends. We need to store the files permanently in other locations, in this project I use Google Drive.

The code below will copy the result files to the project Google Drive folder (the Google Drive folder has been mounted in the earlier step).

In this project, I save the epoch # 4 model file only.

```
!cp 'base_2e-5_1e-8_17_4.answer.txt' 'uiuc/My Drive/cs410/final_project/base_2e-5_1e-8_17_4.answer.txt'
!cp 'base_2e-5_1e-8_17_4.model' 'uiuc/My Drive/cs410/final_project/base_2e-5_1e-8_17_4.model'

!cp 'large_2e-5_1e-8_17_4.answer.txt' 'uiuc/My Drive/cs410/final_project/large_2e-5_1e-8_17_4.answer.txt'
!cp 'large_2e-5_1e-8_17_4.model' 'uiuc/My Drive/cs410/final_project/large_2e-5_1e-8_17_4.model'
```



We use the files stored in the project Google Drive folder to run a project *demo*. The next section will illustrate how to use the trained-model file to evaluate the testing dataset.

F.2. DEMO_Model_Evaluation.ipynb Code Review

In the demo notebook, I demonstrate how to generate ‘answer.txt’ from the BERT Large uncased trained model stored in the project Google Drive folder. The trained-model is available to the public here [link](#). With this model, we will reproduce the evaluation result which is available to the public here [link](#).

The demo video is available here [link](#).

The main algorithm in the notebook demo:

1. *The first 3-steps are already explained in detail in the previous section*

- Colab configuration (Python modules import and installation)
- Copy the trained-model and testing dataset files from Google Drive to the Colab session. We need to authorize Colab to access the Google account described in the previous section.
- Prepare Panda DataFrame for the testing dataset.

2. *Preparing the encoded testing dataset and data loader*

The main steps:

- Create the BERT tokenizer to encode the testing dataset.
- Create the data loader to run the evaluation in batches.

```

# 1. Encode the data
# 2. Create Tensor Dataset
# 3. Create Dataloader for the evaluation

bert_model = 'bert-large-uncased'
batch_size = 5

tokenizer = BertTokenizer.from_pretrained(bert_model, do_lower_case=True)

encoded_data_evaluation = tokenizer.batch_encode_plus(
    df.response.values,
    add_special_tokens=True,
    return_attention_mask=True,
    max_length=max_length,
    padding='max_length',
    return_tensors='pt'
)

input_ids_evaluation = encoded_data_evaluation['input_ids']
attention_masks_evaluation = encoded_data_evaluation['attention_mask']

dataset_evaluation = TensorDataset(input_ids_evaluation, attention_masks_evaluation)

dataloader_eval = DataLoader(dataset_evaluation, sampler=SequentialSampler(dataset_evaluation), batch_size=batch_size)

```

Preparing the Python objects for the evaluation

3. Run the evaluation batch iteration

The main steps:

- Set the device to GPU, if applicable.
- Load the trained model from file to memory.
- Set the model to evaluation mode.
- Data loader iteration to pass text to evaluate in batches to the model.
- The model output logits (how to process logits is described in the previous section)


```

# If GPU is available.
if torch.cuda.is_available():
    # PyTorch to use the GPU
    device = torch.device("cuda")
    print('There are %d GPU(s) available.' % torch.cuda.device_count())
    print('We will use the GPU:', torch.cuda.get_device_name(0))
# If GPU is not available. Use the CPU.
else:
    print('No GPU available, using the CPU instead.')
    device = torch.device("cpu")

# To set the model into a training mode
label_dict = {'SARCASM': 0, 'NOT_SARCASM': 1}

# Load the pre-trained model
model = BertForSequenceClassification.from_pretrained(bert_model,
                                                    num_labels=len(label_dict),
                                                    output_attentions=False,
                                                    output_hidden_states=False)

model.to(device)
model.load_state_dict(torch.load(model_file, map_location=torch.device(device)))

# Set the model to evaluation/testing mode
model.eval()
loss_val_total = 0
predictions = []

# Iterate the evaluation/testing data loader
progress_bar = tqdm(dataloader_eval, leave=False, disable=False)
for batch in progress_bar:
    batch = tuple(b.to(device) for b in batch)
    inputs = {'input_ids': batch[0], 'attention_mask': batch[1]}

    with torch.no_grad():
        # evaluate the validation dataset
        output = model(**inputs)
        logits = output[0]
        logits = logits.detach().cpu().numpy()
        predictions.append(logits)

predictions = np.concatenate(predictions, axis=0)
preds_flat = np.argmax(predictions, axis=1).flatten()

print('#####')
print('# Evaluation is done #')
print('#####')

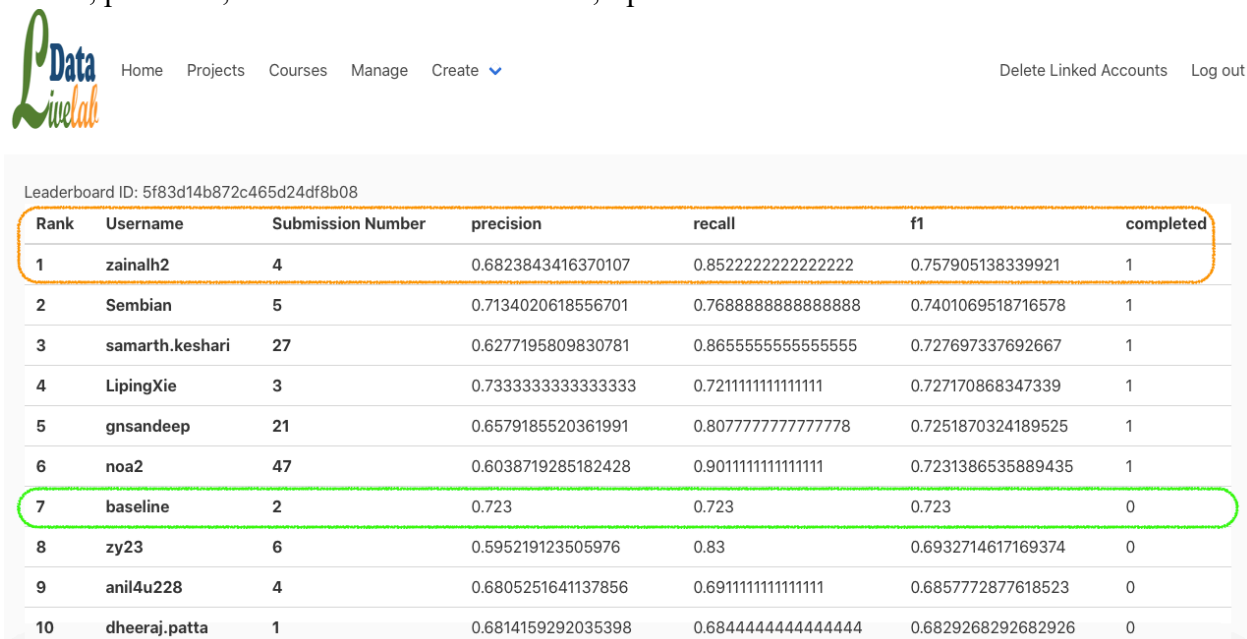
```

4. Generate the 'answer.txt' file

Generate the sentiment output to the screen and 'answer.txt' file. The previous section describes the source code snippet.

5. Post 'answer.txt' to LiveDataLab for scoring

For F1, precision, and recall scores evaluation, I post the 'answer.txt' to LiveDataLab.



Leaderboard ID: 5f83d14b872c465d24df8b08

| Rank | Username | Submission Number | precision | recall | f1 | completed |
|------|-----------------|-------------------|--------------------|--------------------|--------------------|-----------|
| 1 | zainalh2 | 4 | 0.6823843416370107 | 0.8522222222222222 | 0.757905138339921 | 1 |
| 2 | Sembian | 5 | 0.7134020618556701 | 0.7688888888888888 | 0.7401069518716578 | 1 |
| 3 | samarth.keshari | 27 | 0.6277195809830781 | 0.8655555555555555 | 0.727697337692667 | 1 |
| 4 | LipingXie | 3 | 0.7333333333333333 | 0.7211111111111111 | 0.727170868347339 | 1 |
| 5 | gnsandeep | 21 | 0.6579185520361991 | 0.8077777777777778 | 0.7251870324189525 | 1 |
| 6 | noa2 | 47 | 0.6038719285182428 | 0.9011111111111111 | 0.7231386535889435 | 1 |
| 7 | baseline | 2 | 0.723 | 0.723 | 0.723 | 0 |
| 8 | zy23 | 6 | 0.595219123505976 | 0.83 | 0.6932714617169374 | 0 |
| 9 | anil4u228 | 4 | 0.6805251641137856 | 0.6911111111111111 | 0.6857772877618523 | 0 |
| 10 | dheeraj.patta | 1 | 0.6814159292035398 | 0.6844444444444444 | 0.6829268292682926 | 0 |

Leaderboard snapshot on 03-Nov-2020

G. Result and Conclusion

In summary, the testing (evaluation) results from BERT Large and base models:

| Model | F1-Score | Recall | Precision |
|--------------------|--------------------|--------------------|--------------------|
| BERT Large uncased | 0.757905138339921 | 0.8522222222222222 | 0.6823843416370107 |
| BERT Base uncased | 0.7458777885548012 | 0.8544444444444445 | 0.6617900172117039 |

Surprisingly, the base model performs almost as good as the large model. In this project, I did try to use different trained model such as RoBERTa and XLNet (and different hyperparameters), but I could not produce a result higher than **BERT Large uncased score**. The project scope as proposed in the project proposal is to explore BERT hence, I am reporting the result for BERT models only.

In the future, I would like to explore more on the following topics:

- To use advanced machine learning techniques to explore other hyperparameters for BERT models.
- To utilize **both** the context **and** response to training the models. I hypothesize that the context can be used as an additional dataset to train the model.
- To explore another model, such as RoBERTa and XLNet.

Reference

1. Aditya Joshi, Pushpak Bhattacharyya, and Mark J. Carman. 2017. [Automatic Sarcasm Detection: A Survey](#). *ACM Computing Surveys*, 50(5):1–22.
2. Jacob Devlin, Ming-Wei Chang, Kenton Lee, and Kristina Toutanova. 2019. [BERT: Pre-training of Deep Bidirectional Transformers for Language Understanding](#).

Appendix

1. answer.txt

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