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| IE4483 |
| Sentiment Analysis |
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# Chapter 1 Data Processing

## Data Preprocessing Procedures

For this project, we have three models which have their own feature format. However, we have general data cleaning procedures before proceeding to train our models. The procedures are as follows.

* Lowercasing:

All text data is converted to lowercase to maintain consistency and prevent case-related variations.

* Removing Punctuation:

Special characters, punctuation marks, and symbols are removed from the text to focus on meaningful words. As removing them simplifies the data and reduce noise.

* Removing Numbers:

Numerical digits or symbols are excluded from the text data, as the focus is often on the emotional tone rather than numerical values. This might help streamline the text data for better model performance.

* Removing Stopwords:

Common, non-discriminative words (stopwords) are eliminated from the text, such as "the," "and," "is," etc. With this, it can helps in focusing on words that carry more sentiment.

* Removing Duplicated Rows:

Duplicate entries, if present, are removed to ensure data quality and to avoid bias that may arise from duplication. With this, we can maintain a clean and unbiased dataset.

# Chapter 2 Models

## 2.1 BERT model (bert-base-uncased)

BERT (Bidirectional Encoder Representations from Transformers) is an innovative natural language processing (NLP) model. It was pre-trained on a vast amount of unlabelled data, following a time-consuming and expensive process. It can capture bidirectional context information in input sequences due to its complex architecture [1].

#### 2.1.1 Input and Output Dimensions

For input, BERT takes in sequences of tokens, with each token being represented as a vector which then processed in the model. Additionally, attention masks are used to distinguish between padding tokens and actual input tokens. As for the output, it consists of a series of vectors of size H, each of which is a vector that matches an index-matched input token [2].

#### 2.1.2 Model Structure

BERT architecture starts with a Token Embedding Layer which is for converting input tokens into vector representation. This layer makes it easier for discrete tokens to be converted into continuous-valued vector. This allows the model to capture the meaning found in the input sequence. The model then includes a multi-layer transformer encoder, and each consist of multiple self-attention layers. This allows the model to focus on different parts of the input sequence and identify long-range dependencies. For the bert-base-uncased model, it consists of 12 layers, and each layer helps to extract and refine contextual information from the embedded token. Following that, we have an Outer Layer which is responsible for making the final predictions such as classifying the sentiment or answering a question [3] [4].

#### 2.1.3 Loss Function

We used Cross-Entropy Loss for the loss function which is a standard choice for binary classification tasks. This measures the dissimilarity between predicted outcomes and actual labels [5].

#### 2.1.4 Training Strategy

The training strategy for the model involves batches of data, each with a specified number of input sequences and corresponding labels. Firstly, we used AdamW optimizer which is an improved Adam optimizer with weight decay capabilities. When it is combined with specified learning rate, this optimizer helps to update the weight efficiently throughout the training iterations [6]. Secondly, the number of epochs (num\_train\_epochs) is set 3 in this project. With each epoch, the training dataset is fully explored which allows the model to gradually refine its parament and enhance its predictive capabilities. Moreover, we have evaluation phase after each training which allow us to gain an insights into the model performance and help find any overfitting or underfitting issues.

#### 2.1.5 Feature Format

As we will be using the Bert Base model, the chosen feature format is tokenized and encoded text data. This format is a standard practice in NLP and ensures that textual data can be effectively utilized by the model for sentiment classification. Below are the steps that the unprocessed data goes through to become a suitable format to be used in the model.

1. Text Cleaning:

* Lowercasing: All text data is converted to lowercase to maintain consistency and prevent case-related variations.
* Removing Punctuation: Special characters, punctuation marks, and symbols are removed from the text to focus on meaningful words.
* Removing Numbers: Numerical digits or symbols are excluded from the text data, as they may not be relevant for sentiment analysis.
* Removing Stopwords: Common, non-discriminative words (stopwords) are eliminated from the text, such as "the," "and," "is," etc.
* Removing Duplicated Rows: Duplicate entries, if present, are removed to ensure data quality.

1. Tokenization:

Breaking down text into subword units is an important step in NLP. When using BERT, words are represented as subword pieces through subword tokenization. This process relies on a trained tokenizer which can be found in the Hugging Face Transformers library.

1. Padding and Truncation:

BERT models require input sequences with a fixed length. To achieve this, padding is used to extend shorter sequences and truncation is used to shorten longer sequences. This ensures that all input sequences have the same length.

1. Encoding:

Text data is converted into numerical values that can be understood by the BERT model. The encoding process involves;

* input\_ids: A series of integer IDs that represent the tokens.
* attention\_mask: A binary mask that distinguishes between actual tokens and padding tokens.
* token\_type\_ids: Utilized to differentiate between two distinct sentence inputs. It is not used for BERT but included for compatibility.

#### 2.1.6 Code and Instruction

I have written the instruction and explanation of some of the codes below.

# Install the required packages by running the following commands in Jupyter Notebook or Python script

!pip install transformers

!pip install accelerate>=0.20.1

# Copy and paste the following imports at the beginning of your script

import pandas as pd

import torch

from transformers import BertForSequenceClassification, AutoTokenizer, BertTokenizer, Trainer, TrainingArguments

from sklearn.model\_selection import train\_test\_split

from torch.utils.data import DataLoader, Dataset

from sklearn.metrics import classification\_report

# Replace the file path in the pd.read\_csv function with the path to your training data CSV file.

data = pd.read\_csv('/content/drive/MyDrive/Colab Notebooks/IE4483/data/processed\_train\_data.csv')

model\_name = "bert-base-uncased"

tokenizer = AutoTokenizer.from\_pretrained(model\_name)

X\_train, X\_test, y\_train, y\_test = train\_test\_split(data['reviews'], data['sentiments'], test\_size=0.2, random\_state=42)

X\_train = X\_train.astype(str).tolist()

X\_test = X\_test.astype(str).tolist()

y\_train = y\_train.tolist()

y\_test = y\_test.tolist()

# This is to define a custom dataset class for text data

class SentimentTextDataset(Dataset):

    def \_\_init\_\_(self, text, labels, tokenizer, max\_length):

        self.encodings = tokenizer(

            text,

            truncation=True,

            padding='max\_length',

            max\_length=max\_length,

            return\_tensors='pt',

        )

        self.labels = labels

    def \_\_len\_\_(self):

        return len(self.labels)

    def \_\_getitem\_\_(self, idx):

        item = {

            'input\_ids': self.encodings['input\_ids'][idx],

            'attention\_mask': self.encodings['attention\_mask'][idx],

            'token\_type\_ids': self.encodings['token\_type\_ids'][idx],  # Not used for BERT, but included for compatibility

            'labels': torch.tensor(self.labels[idx]),

        }

        return item

max\_length = 128

train\_dataset = SentimentTextDataset(X\_train, y\_train, tokenizer, max\_length)

eval\_dataset = SentimentTextDataset(X\_test, y\_test, tokenizer, max\_length)

# The training arguments

training\_args = TrainingArguments(

    output\_dir="./sentiment\_model",

    num\_train\_epochs=3,

    per\_device\_train\_batch\_size=8,

    per\_device\_eval\_batch\_size=8,

    evaluation\_strategy="epoch",

    save\_total\_limit=2,

)

model = BertForSequenceClassification.from\_pretrained(model\_name, num\_labels=2)  # num\_labels=2 for binary classification

trainer = Trainer(

    model=model,

    args=training\_args,

    train\_dataset=train\_dataset,

    eval\_dataset=eval\_dataset,

)

trainer.train()

# Save the fine-tuned model to the specified directory

trainer.save\_model("/content/drive/MyDrive/Colab Notebooks/IE4483/model/BERT")

# This is to evaluate the model and generate a classification report

# Replace the file path with the correct path to the trained model

model = BertForSequenceClassification.from\_pretrained("/content/drive/MyDrive/Colab Notebooks/IE4483/model/BERT")

eval\_dataloader = DataLoader(eval\_dataset, batch\_size=8)

model.eval()

predicted\_labels = []

true\_labels = []

with torch.no\_grad():

    for batch in eval\_dataloader:

        input\_ids = batch['input\_ids'].to(model.device)

        attention\_mask = batch['attention\_mask'].to(model.device)

        labels = batch['labels'].to(model.device)

        outputs = model(input\_ids, attention\_mask=attention\_mask)

        predicted\_labels.extend(outputs.logits.argmax(dim=1).cpu().numpy())

        true\_labels.extend(labels.cpu().numpy())

# This is to generate a classification report

report = classification\_report(true\_labels, predicted\_labels, target\_names=["Class 0", "Class 1"])

print(report)

### 2.1.7 Parameter and Setting Selection

Maximum Sequence Length (max\_length)

After weighing the trade-offs between computational efficiency and model complexity, we chose to set max\_length at 128. With this, we can maintain reasonable computing requirements while capturing context. While using a lesser length could mean losing important contextual information, using a greater length would need more computational resources.

Number of Training Epochs (num\_train\_epochs)

Initially, we started with three training epochs. By allowing the model to go through training iterations, this value helps the model identify the sentiment patterns that are underlying the data. We can identify the ideal balance between training time and model convergence by experimenting with the number of training epochs. The model achieve 92% accuracy so I believe the decision to use three training epochs is good.

Number of Labels (num\_labels)

For binary sentiment analysis, it is appropriate to set num\_labels to 2. This selection illustrates the task's binary nature where the objective is to categorize the data as a positive or negative sentiment.

## 2.2 Convolutional Neural Network

A convolutional neural network is a network architecture for deep learning that learns directly from data, it can uncover key information in both time series and image data.

#### 2.2.1 Input and Output Dimensions

The input dimension is set to max\_length = 64, after trying a few more max\_length values such as 32 and 128, the model with 64 as input dimension gave the highest accuracy.

The output dimension is set to be determined by the number of unique labels in the training data using num\_classes = len(set(y\_train));

#### 2.2.2 Model Structure

CNN contains several layers that serves different functions.

1. Embedding layer that converts sequences of integers to dense vectors
2. Convolutional layer (Conv1D) which learns features by sliding filter over input data. Most computations happen in the convolutional layer.
3. Pooling layer (GlobalMaxPooling1D) that reduces the dimension of the data from output of previous layer. In max pooling, the maximum value from each feature map is extracted.
4. Fully Connected layer (Dense) that learns complex pattern from output of previous layers using the ReLU activation function which helps to add non-linearity.
5. Dropout layer that helps prevent overfitting by randomly setting some input value to 0.
6. Output dense layer that uses SoftMax activation function to output a probability distribution over the possible classes.

#### 2.2.3 Loss Function

The loss function is computed using the Sparse Categorical Cross Entropy, a loss function that is commonly used for classification problem which labels are integers. The output probability distribution obtained is compared against the ground truth and compute the loss. The overall loss is the average of individual loss of all examples.

#### 2.2.4 Training Strategy

Adam optimiser is used in this model training, iteratively adjusting the hyperparameter to increase the accuracy and lower the degree of error. Adam optimiser is a descent-based optimiser that adjust learning rate adaptively based on both the history of gradient calculated and the magnitude of recent gradients. It computes individual adaptive learning rates for different parameters from estimates of first and second moments of the gradients.

The data is trained in batches of 32 over an epoch of 10. Various combination of values that involve increasing or decreasing batch sizes and number of epochs are tested out and this gives the highest accuracy.

#### 2.2.5 Feature Format

Apart from the data cleaning adapted in chapter 1, the data is tokenised, from sequence of text to individual unit, which is essential for vocabulary creation and helps segment sentences into meaningful units for analysis. The data is then padded to the maximum length, calculated by finding the longest data. Padding is essential for all the sequences to have the same length. The data is then converted to list and is ready to use.

#### 2.2.6 Code and Instruction

import tensorflow as tf

import numpy as np

from sklearn.model\_selection import train\_test\_split

from tensorflow.keras.preprocessing import sequence

from tensorflow.keras.preprocessing.text import Tokenizer

from tensorflow.keras.models import Sequential

from tensorflow.keras.layers import Embedding, Conv1D, GlobalMaxPooling1D, Dense, Dropout

max\_words = 64

# Split the data into training and testing sets

X\_train, X\_test, y\_train, y\_test = train\_test\_split(

train\_df['reviews'], train\_df['sentiments'], test\_size=0.2, random\_state=1

)

# Tokenization

tokenizer = Tokenizer(num\_words=max\_words, oov\_token='<OOV>')

tokenizer.fit\_on\_texts(X\_train)

X\_train\_sequences = tokenizer.texts\_to\_sequences(X\_train)

X\_test\_sequences = tokenizer.texts\_to\_sequences(X\_test)

# Padding

max\_length = max(len(seq) for seq in X\_train\_sequences)

X\_train\_padded = sequence.pad\_sequences(X\_train\_sequences, maxlen=max\_length)

X\_test\_padded = sequence.pad\_sequences(X\_test\_sequences, maxlen=max\_length)

# Convert labels to NumPy arrays

y\_train = np.array(y\_train)

y\_test = np.array(y\_test)

# Create the CNN model

embedding\_dim = 50

num\_classes = len(set(y\_train))

model = Sequential()

model.add(Embedding(input\_dim=max\_words, output\_dim=embedding\_dim, input\_length=max\_length))

model.add(Conv1D(128, 5, activation='relu'))

model.add(GlobalMaxPooling1D())

model.add(Dense(128, activation='relu'))

model.add(Dropout(0.5))

model.add(Dense(num\_classes, activation='softmax'))

# Compile the model

model.compile(optimizer='adam', loss='sparse\_categorical\_crossentropy', metrics=['accuracy'])

# Train the model

batch\_size = 32

epochs = 10

model.fit(X\_train\_padded, y\_train, validation\_data=(X\_test\_padded, y\_test), batch\_size=batch\_size, epochs=epochs)

# Evaluate the model on test set

test\_loss, test\_acc = model.evaluate(X\_test\_padded, y\_test)

print(f'Test Accuracy: {test\_acc \* 100:.2f}%')

## 2.3 Recurrent Neural Network

Recurrent Neutral Network (RNN) is a neutral network that is useful for sequential data such as speech, text and language. Due to having internal memory, RNN remembers the inputs they received and hence used them in their subsequent output predictions.

#### 2.3.1 Input and Output Dimensions

#### 2.3.2 Model Structure

Embedding layer: This layer is used to transform input text data into low-dimensional vector space. This helps to capture semantic relationships between words as they are being mapped out. [<https://www.baeldung.com/cs/neural-nets-embedding-layers#:~:text=In%20summary%2C%20we%20use%20embedding,is%20a%20specific%20input%20feature.>]

Long Short Term Memory (LSTM) layer – It is used to learn long-range connections for text sequences and understanding sequential patterns within the textual data [<https://www.analyticsvidhya.com/blog/2022/01/sentiment-analysis-with-lstm/>]

Dense layer - Used to make predictions based on the representations learnt from the previous layers.

#### 2.3.3 Loss Function

In the case of a recurrent neural network, the loss function *L*L of all time steps is defined based on the loss at every time step as follows:

#### 2.3.4 Training Strategy

#### 2.3.5 Feature Format

#### 2.3.6 Code and Instruction

#### 2.3.7 Parameter and Setting Selection

Embedding layer (embedding\_size)

The embedding layer is used to convert each word index into a dense vector of fixed sizes.

## 2.4 Model Selection and Result

Since Bert model has the highest accuracy of 92% among other models. We choose this model to predict the given test set.

# Chapter 3 Evaluation of the Model

To discuss the strength and weakness of the model, we will analyse two cases, one incorrectly classified and one correctly classified.

Incorrectly Classified Review: “love naughty monkey im happy shoes dont hurt feet”

The review has positive sentiment which are “love” and “happy”, but it was classified as negative. This might be because the model has difficulty understand the specific phrases like “naughty monkey”. Hence, the model might lack context or semantic understanding of certain expressions which lead to misinterpretation of sentiment.

Correctly Classified Review: “shades great buy fast shipping great price good quality”

The review has words such as “great buy”, “fast shipping” and “good quality” and the model correctly identifies this review as a positive sentiment. This demonstrate that the model can capture and combine a various positive phrase to capture positive sentiment.

In summary, the strength is that it is able to identify and group positive phrases which help with accurate positive sentiment classification. However, the model has difficulty with some expression which lead to misclassification.

### Impact on Resource Consumption and Accuracy

Since BERT is a pre-trained model, we typically use tokenization and input encoding as the primary feature format. Moreover, BERT handles embeddings, attention masks and streamline the feature preparing process so we do not need to explicitly specify them. Hence, we will be discussing other feature format such as Word Embedding and Bag-of-Word (BoW) that can impact the resource consumption and accuracy if we use other than BERT.

In general, word embeddings can have a lower memory consumption, but the size of embedding vectors and vocabulary size may influence the memory usage. Additionally, they can capture semantic relationships between words but with complex context, their accuracy will be lower [7]. Similarly, BoW have lower resource consumption which make it suitable for large dataset. However, it disregards word order and context which make it unsuitable for this sematic classification tasks as it requires understanding of sequential information. With that, it might not capture the full semantic meaning which results in lower accuracy [8] [9].

# Chapter 4 Hotel Reviews

### 4.1.1 Dataset without rating score

* since it is already pretrained on large dataset and learned sentiment related stuff, it can still recognize sentiment pattern
* can do custom tokenization so that model can recognize the expression in hotel review

<https://medium.com/@shankar.arunp/training-bert-from-scratch-on-your-custom-domain-data-a-step-by-step-guide-with-amazon-25fcbee4316a>

<https://www.analyticsvidhya.com/blog/2020/07/transfer-learning-for-nlp-fine-tuning-bert-for-text-classification/>

MLM is a type of pre-training that is utilized to train transformer-based language models, such as BERT

Some examples of domain-specific LLMs include [LEGAL-BERT](https://arxiv.org/abs/2010.02559) trained on legislation, court cases, and contracts, [FinBERT](https://arxiv.org/abs/1908.10063) trained on financial services corpus and [BioBERT](https://arxiv.org/abs/1901.08746) trained on biomedical literature. Both of these models are available for public use in the HuggingFace hub for free.

Discuss how your classification algorithm would perform in this new

project and how can it be modified to perform well in this new problem.

Bert models are usually pre-trained with large dataset

### 4.1.1 Dataset with inaccurate rating score

* semi supervised learning
* domain specific knowledge

<https://aclanthology.org/2022.insights-1.8.pdf>

<https://www.researchgate.net/publication/371123744_Handling_Realistic_Label_Noise_in_BERT_Text_Classification>

## Contribution

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