Yelp Reviews - Sentiment Analysis

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1. 資料前處理

- 載入原始資料集

```python
import pandas as pd

df = pd.read_csv("yelp.csv")
df.head()
```

	business_id	date	review_id	stars	text	type	user_id	cool	useful	funny
0	9yKzy9PApeiPPOUJEtnvkg	2011-01-26	fWKvX83p0-ka4JS3dc6E5A	5	My wife took me here on my birthday for breakf...	review	rLtl8ZkDX5vH5nAx9C3q5Q	2	5	0
1	ZRJwVLyzEJq1VAihDhYiow	2011-07-27	IjZ33sJrzXqU-0X6U8NwyA	5	I have no idea why some people give bad review...	review	0a2KyEL0d3Yb1V6aivbIuQ	0	0	0
2	6oRAC4uyJCsJl1X0WZpVSA	2012-06-14	IESLBzqUCLdSzSqm0eCSxQ	4	love the gyro plate. Rice is so good and I als...	review	0hT2KtfLiobPvh6cDC8JQg	0	1	0
3	_1QQZuf4zZOyFCvXc0o6Vg	2010-05-27	G-WvGaISbqqaMHlNnByodA	5	Rosie, Dakota, and I LOVE Chaparral Dog Park!!...	review	uZetl9T0NcROGOyFfughhg	1	2	0
4	6ozycU1RpktNG2-1BroVtw	2012-01-05	1uJFq2r5QfJG_6ExMRCaGw	5	General Manager Scott Petello is a good egg!!!...	review	vYmM4KTsC8ZfQBg-j5MWkw	0	0	0

- 只保留stars和text兩個會用在情緒分析的欄位

```python
#only preservve the stars and text columns
df = df[['stars', 'text']]
df.head()
```

	stars	text
0	5	My wife took me here on my birthday for breakf...
1	5	I have no idea why some people give bad review...
2	4	love the gyro plate. Rice is so good and I als...
3	5	Rosie, Dakota, and I LOVE Chaparral Dog Park!!...
4	5	General Manager Scott Petello is a good egg!!!...

- 將stars欄位當中的值，以大於等於4作為標準進行binary數值的轉換

```python
#switch the stars to binary (1 for positive, 0 for negative sentiment)
df['stars'] = df['stars'].apply(lambda x: 1 if x >= 4 else 0)
df.head()
```

	stars	text
0	1	My wife took me here on my birthday for breakf...
1	1	I have no idea why some people give bad review...
2	1	love the gyro plate. Rice is so good and I als...
3	1	Rosie, Dakota, and I LOVE Chaparral Dog Park!!...
4	1	General Manager Scott Petello is a good egg!!!...

- 將text欄位內的文字內容轉換成串列

```
#use separator to split the text into words
df['text'] = df['text'].str.split()
df.head()
```

	stars	text
0	1	[My, wife, took, me, here, on, my, birthday, f...
1	1	[I, have, no, idea, why, some, people, give, b...
2	1	[love, the, gyro, plate., Rice, is, so, good, ...
3	1	[Rosie,, Dakota,, and, I, LOVE, Chaparral, Dog...
4	1	[General, Manager, Scott, Petello, is, a, good...

- 載入nltk套件並且下載stopwords的資料

```
import nltk
nltk.download('stopwords')
```

```
[nltk_data] Downloading package stopwords to
[nltk_data]     C:\Users\a0905\AppData\Roaming\nltk_data...
[nltk_data]   Package stopwords is already up-to-date!

True
```

- 將text欄位中的停頓詞(stopwords)去除

```
#remove stop words in the text
from nltk.corpus import stopwords

stop_words = set(stopwords.words('english'))
df['text'] = df['text'].apply(lambda x: [word for word in x if word not in stop_words])
df.head()
```

	stars	text
0	1	[My, wife, took, birthday, breakfast, excellen...
1	1	[I, idea, people, give, bad, reviews, place., ...
2	1	[love, gyro, plate., Rice, good, I, also, dig,...
3	1	[Rosie,, Dakota,, I, LOVE, Chaparral, Dog, Par...
4	1	[General, Manager, Scott, Petello, good, egg!!...

- 將text欄位當中的串列值轉換回字串

```
# Ensure all rows in 'text' are strings
df['text'] = df['text'].apply(lambda x: ' '.join(x) if isinstance(x, list) else x)
df.head()
```

	stars	text
0	1	My wife took birthday breakfast excellent. The...
1	1	I idea people give bad reviews place. It goes ...
2	1	love gyro plate. Rice good I also dig candy se...
3	1	Rosie, Dakota, I LOVE Chaparral Dog Park!!! It...
4	1	General Manager Scott Petello good egg!!! Not ...

- 用tf-idf的技術將text欄位當中的字串轉換成向量(vector)

```
#Text mining preprocessing, converting text into vectors, implement tf-idf (sklearn.feature_extraction.text.TfidfVectorizer)

from sklearn.feature_extraction.text import TfidfVectorizer

tfidf = TfidfVectorizer()

#Apply tf-idf to the "Text" column
tfidf_matrix = tfidf.fit_transform(df['text']).toarray()  # Convert sparse to dense
tfidf_matrix
```

```
array([[0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       ...,
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.],
       [0., 0., 0., ..., 0., 0., 0.]])
```

- 將資料進行分割，以80%/20%的比例分成訓練集和測試集，並且再把80%的訓練集再分成75%的訓練集和25%的驗證集

```
#split the data into training and testing sets
from sklearn.model_selection import train_test_split
X_train, X_test, y_train, y_test = train_test_split(tfidf_matrix, df['stars'], test_size=0.2, random_state=42)
#split the training data into training and validation sets
X_train, X_val, y_train, y_val = train_test_split(X_train, y_train, test_size=0.25, random_state=42)
```

---

2. CNN模型

卷積神經網路（CNN, Convolutional Neural Network）是一種常用於圖像處理和其他類型的數據分析的深度學習模型

- 1.卷積層（Convolutional Layer）
  - 這是CNN的核心，負責提取圖像中的特徵。卷積層使用卷積運算將filter（又稱為kernel）應用於輸入圖像，生成特徵圖（Feature Map）
  - 卷積運算可以幫助模型識別圖像中的邊緣、形狀和其他基本特徵
- 2.激活函數（Activation Function）

- 通常在卷積層後面會使用激活函數（如ReLU）來引入非線性，使得網絡能夠學習更複雜的特徵
  - 激活函數的作用是將卷積層的輸出轉換為更有用的數值範圍
- 3.池化層（Pooling Layer）
  - 池化層常用來縮小特徵圖的尺寸（降維），常見的池化方式有最大池化（Max Pooling）和平均池化（Average Pooling）
  - 池化層有助於減少計算量，降低overfitting的風險，並且使得特徵具有平移不變性
- 4.全連接層（Fully Connected Layer）
  - 在CNN的最後，通常會有一層或多層全連接層，用來將提取到的特徵映射到最終的輸出類別（如圖片分類結果）
  - 全連接層中的每一個神經元都與前一層的所有神經元相連
- 5.輸出層（Output Layer）
  - 輸出層的神經元數量等於分類的類別數。對於二分類問題，通常會使用sigmoid激活函數；對於多分類問題，則會使用softmax激活函數
- 6.優化器（Optimizer）和損失函數（Loss Function）
  - 優化器（如Adam、SGD）用來更新網路中的權重，目的是最小化損失函數
  - 損失函數衡量預測值與實際值之間的誤差，通過反向傳播來調整網絡權重，達到更好的預測效果

CNN的特點:

- 特徵自動提取：CNN不需要手動提取特徵，它能夠自動學習和提取圖像中的關鍵特徵
- 局部連接：每個神經元只與上一層的一部分神經元相連，這有助於減少參數數量
- 權重共享：卷積層中的filter在整個圖像中共享權重，進一步減少了參數的數量

程式碼截圖

- 建立結構簡單的CNN模型用來訓練情緒分析的能力

```
#build the CNN model
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Embedding, Conv1D, MaxPooling1D, Flatten, Dense
from tensorflow.keras.layers import Dropout

#add dropout layer to avoid overfitting
model = Sequential()
model.add(Embedding(input_dim=tfidf_matrix.shape[1], output_dim=128, input_length=tfidf_matrix.shape[1]))
model.add(Conv1D(filters=128, kernel_size=3, activation='relu'))
model.add(MaxPooling1D(pool_size=5))
model.add(Conv1D(filters=64, kernel_size=3, activation='relu'))
model.add(MaxPooling1D(pool_size=2))
model.add(Flatten())
model.add(Dense(64, activation='relu'))
model.add(Dropout(0.7))
model.add(Dense(1, activation='sigmoid'))

model.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])

c:\Users\a0905\AppData\Local\Programs\Python\Python312\Lib\site-packages\keras\src\layers\core\embedding.py:90: UserWarning: Argument `input_length` is deprecated. Just remove it.
  warnings.warn(
```

- 印出所建構出的CNN模型的架構

```
#show CNN model structure
print(model.summary())
```

```
Model: "sequential"
```

Layer (type)	Output Shape	Param #
embedding (Embedding)	(None, 29183, 128)	3,735,424
conv1d (Conv1D)	(None, 29181, 128)	49,280
max_pooling1d (MaxPooling1D)	(None, 5836, 128)	0
conv1d_1 (Conv1D)	(None, 5834, 64)	24,640
max_pooling1d_1 (MaxPooling1D)	(None, 2917, 64)	0
flatten (Flatten)	(None, 186688)	0
dense (Dense)	(None, 64)	11,948,096
dropout (Dropout)	(None, 64)	0
dense_1 (Dense)	(None, 1)	65

```
Total params: 47,272,517 (180.33 MB)

Trainable params: 15,757,505 (60.11 MB)

Non-trainable params: 0 (0.00 B)

Optimizer params: 31,515,012 (120.22 MB)

None
```

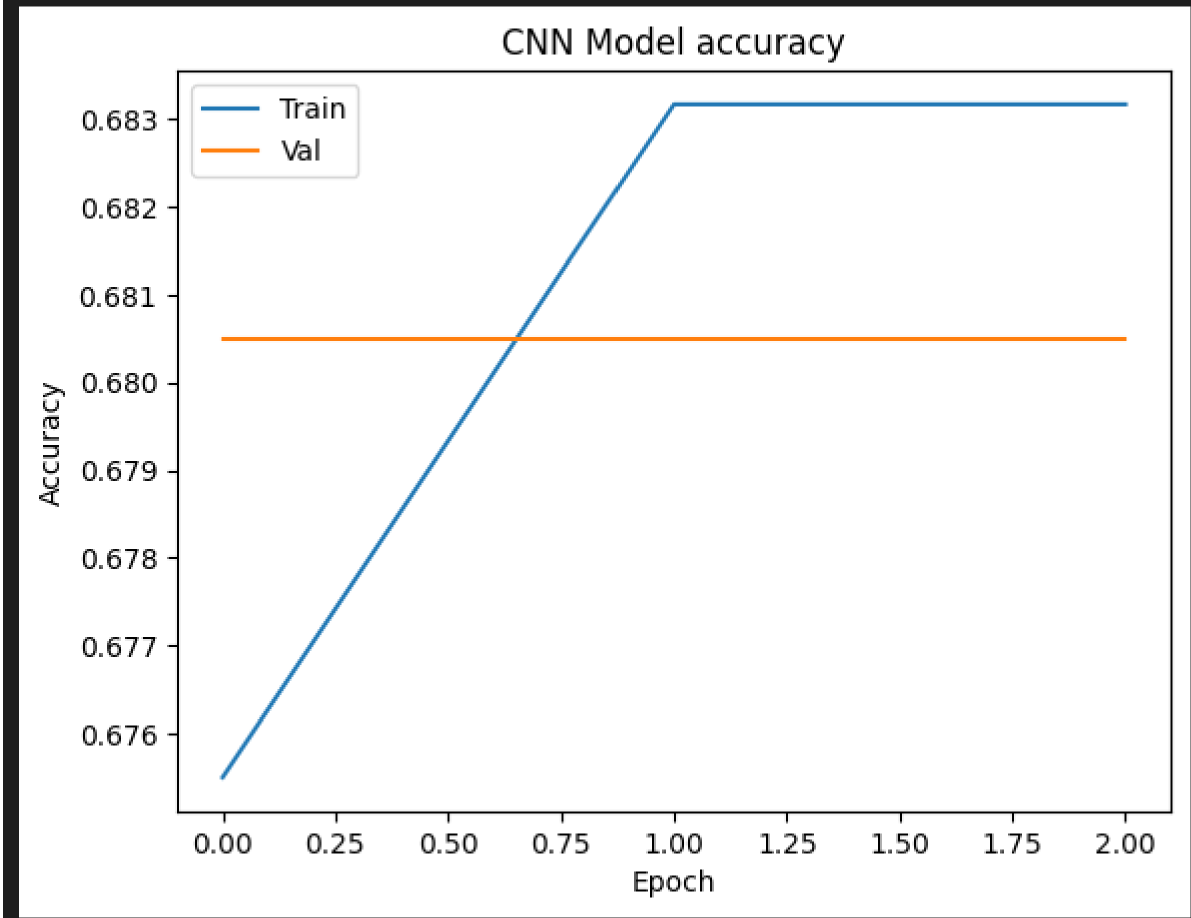
- 用建立完的CNN模型以切割出的訓練集和測試集進行訓練

```
#train the model
history = model.fit(X_train, y_train, epochs=3, batch_size=32, validation_data=(X_val, y_val))
```

```
Epoch 1/3
188/188 ━━━━━━━━━━━━━━━━━━━━ 299s 2s/step - accuracy: 0.6676 - loss: 0.6978 - val_accuracy: 0.6805 - val_loss: 0.6339
Epoch 2/3
188/188 ━━━━━━━━━━━━━━━━━━━━ 296s 2s/step - accuracy: 0.6740 - loss: 0.6587 - val_accuracy: 0.6805 - val_loss: 0.6310
Epoch 3/3
188/188 ━━━━━━━━━━━━━━━━━━━━ 297s 2s/step - accuracy: 0.6758 - loss: 0.6460 - val_accuracy: 0.6805 - val_loss: 0.6287
```

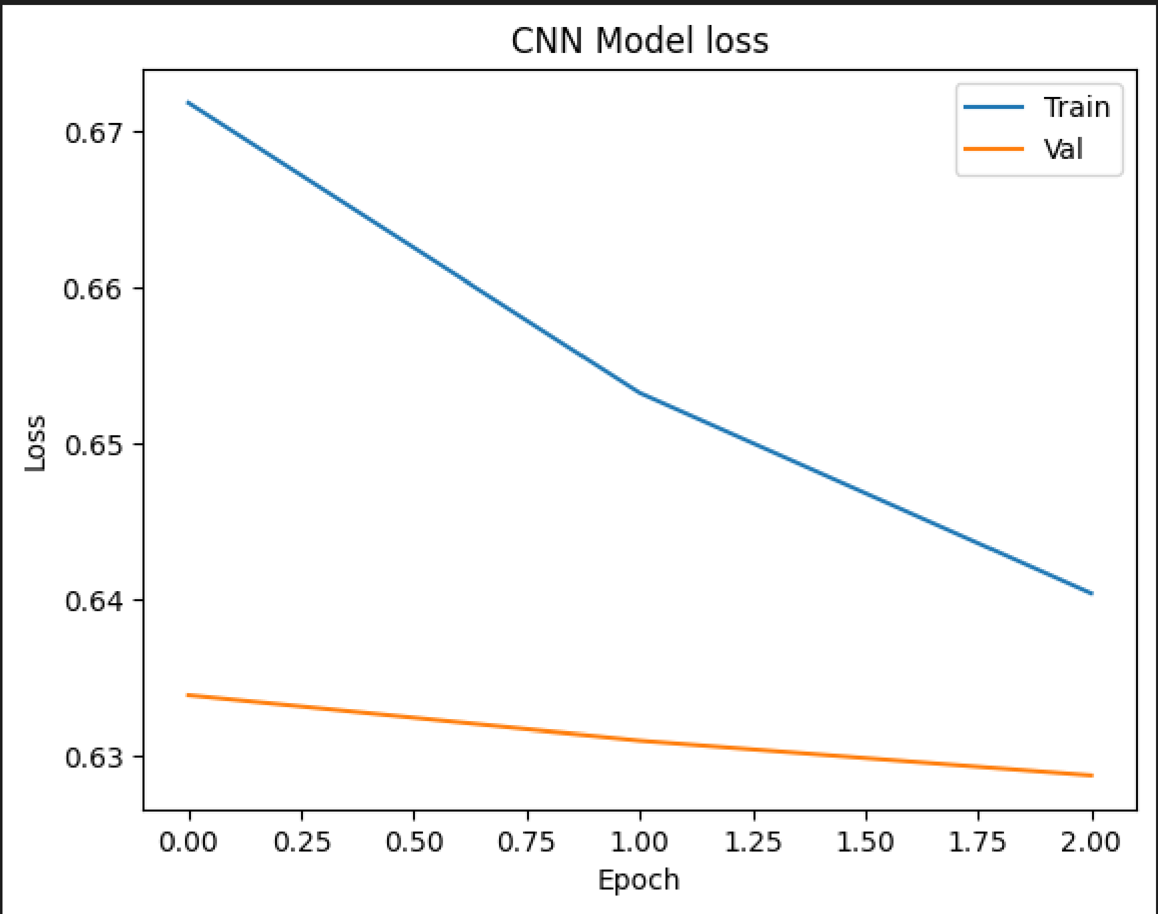
- 繪製每個epoch的training accuracy和validation accuracy的變化圖

```python
#plot the trainging process for the CNN model and show accuracy and loss
import matplotlib.pyplot as plt
plt.plot(history.history['accuracy'])
plt.plot(history.history['val_accuracy'])
plt.title('CNN Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Val'], loc='best')
plt.show()
```



- 繪製每個epoch的training loss和validation loss的變化圖

```
#plot the trainging process for the CNN model and show accuracy and loss
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('CNN Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Val'], loc='best')
plt.show()
```



- 用測試集的資料評估訓練出的CNN模型在情緒分析任務上的表現

```
#show accuracy on test data
scores = model.evaluate(X_test, y_test)
print("Accuracy: ", scores[1])
```

```
63/63 ━━━━━━━━━━━━━━━━━━━━ 9s 145ms/step - accuracy: 0.6915 - loss: 0.6220
Accuracy:  0.7014999985694885
```

---

3. LSTM模型

長短期記憶網路（LSTM, Long Short-Term Memory）是一種特殊的循環神經網絡（RNN），用於處理和預測序列數據，特別擅長解決傳統RNN在長期依賴問題中的局限

- 1.LSTM的基本結構
    - LSTM包含一組特殊的記憶單元（memory cell），每個記憶單元都有三個主要的閘控結構：輸入閘（Input Gate）、遺忘閘（Forget Gate）和輸出閘（Output Gate）
    - 這些閘控決定了信息的傳遞方式，控制哪些資訊被記住、丟棄或傳遞給下一層
- 2.遺忘閘（Forget Gate）
    - 遺忘閘決定哪些資訊從單元的記憶中丟棄。它會根據當前輸入和前一狀態的輸出生成一個0到1之間的值，這個值用來乘以記憶單元的狀態，表示丟棄多少資訊
- 3.輸入閘（Input Gate）
    - 輸入閘控制哪些新資訊將被加入到單元的記憶中。它同樣生成一個0到1之間的值，並將其與當前的輸入進行加權後，更新記憶單元的狀態
- 4.輸出閘（Output Gate）
    - 輸出閘決定了記憶單元的哪些部分將被用來產生當前的輸出。它會根據當前的輸入和內部狀態生成一個0到1之間的值，這個值用來調節記憶單元狀態的輸出
- 5.記憶單元狀態更新
    - 記憶單元的狀態是LSTM的關鍵，它會結合遺忘閘的操作（丟棄部分舊資訊）和輸入閘的操作（加入新的資訊）進行更新，從而使得LSTM能夠記住關鍵的長期資訊
- 6.避免梯度消失(Gradient Vanishing)與梯度爆炸(Gradient Exploding)問題
    - 傳統的RNN在處理長序列時會遇到梯度消失或梯度爆炸的問題，而LSTM通過引入記憶單元和閘控結構，有效地解決了這些問題，使得LSTM可以學習長期依賴的關係

LSTM的特點：

- 1.長期依賴
    - LSTM能夠記住長期依賴關係，特別適合處理長序列數據，如語音識別、語言建模等
- 2.閘控結構
    - LSTM的閘控結構使得它可以動態地選擇性地儲存或遺忘資訊，從而更靈活地捕捉數據中的時間依賴性
- 3.避免RNN的缺陷

- 相比傳統RNN，LSTM能夠更好地處理長期依賴問題，避免了梯度消失或爆炸的問題

程式碼截圖

- 建立結構簡單的LSTM模型用來訓練情緒分析的能力

```
#build the LSTM model
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Embedding, LSTM, Dense
from tensorflow.keras.layers import SpatialDropout1D

model_lstm = Sequential()
model_lstm.add(Embedding(input_dim=tfidf_matrix.shape[1], output_dim=128, input_length=tfidf_matrix.shape[1]))
model_lstm.add(SpatialDropout1D(0.7))
model_lstm.add(LSTM(64, dropout=0.2, recurrent_dropout=0.2))
model_lstm.add(Dense(1, activation='sigmoid'))

model_lstm.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])
```

```
c:\Users\a0905\AppData\Local\Programs\Python\Python312\Lib\site-packages\keras\src\layers\core\embedding.py:90: UserWarning: Argument `input_length` is deprecated. Just remove it.
  warnings.warn(
```

- 印出所建構出的LSTM模型的架構

```
#show LSTM model structure
print(model_lstm.summary())
```

Model: "sequential_1"

Layer (type)	Output Shape	Param #
embedding_1 (Embedding)	(None, 29183, 128)	3,735,424
spatial_dropout1d (SpatialDropout1D)	(None, 29183, 128)	0
lstm (LSTM)	(None, 64)	49,408
dense_2 (Dense)	(None, 1)	65

```
Total params: 11,354,693 (43.31 MB)

Trainable params: 3,784,897 (14.44 MB)

Non-trainable params: 0 (0.00 B)

Optimizer params: 7,569,796 (28.88 MB)

None
```

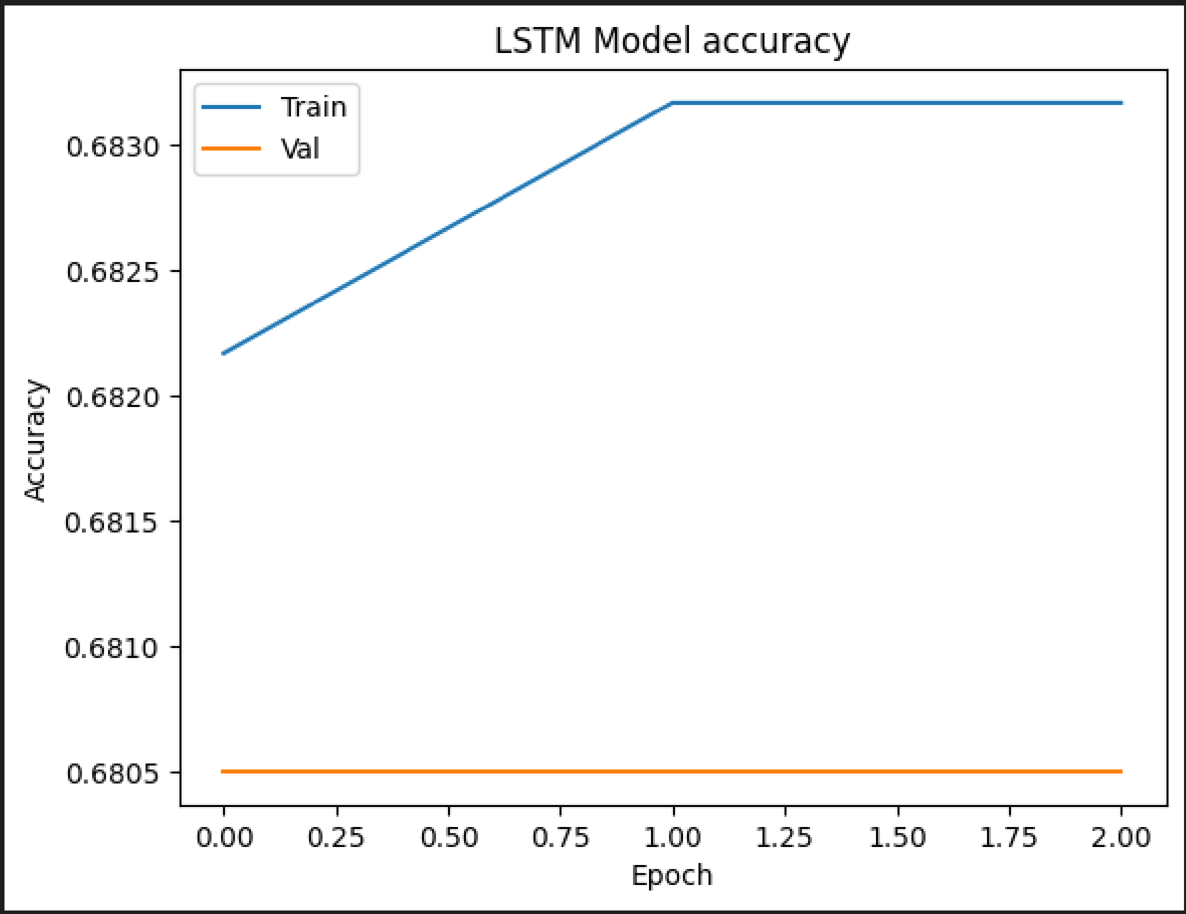
- 用建立完的LSTM模型以切割出的訓練集和測試集進行訓練

```
#train the LSTM model
history_lstm = model_lstm.fit(X_train, y_train, epochs=3, batch_size=32, validation_data=(X_val, y_val))
```

```
Epoch 1/3
188/188 ━━━━━━━━━━━━━━━━━━━━ 14560s 77s/step - accuracy: 0.6876 - loss: 0.6310 - val_accuracy: 0.6805 - val_loss: 0.6265
Epoch 2/3
188/188 ━━━━━━━━━━━━━━━━━━━━ 14386s 77s/step - accuracy: 0.6787 - loss: 0.6302 - val_accuracy: 0.6805 - val_loss: 0.6347
Epoch 3/3
188/188 ━━━━━━━━━━━━━━━━━━━━ 14502s 77s/step - accuracy: 0.6909 - loss: 0.6207 - val_accuracy: 0.6805 - val_loss: 0.6265
```

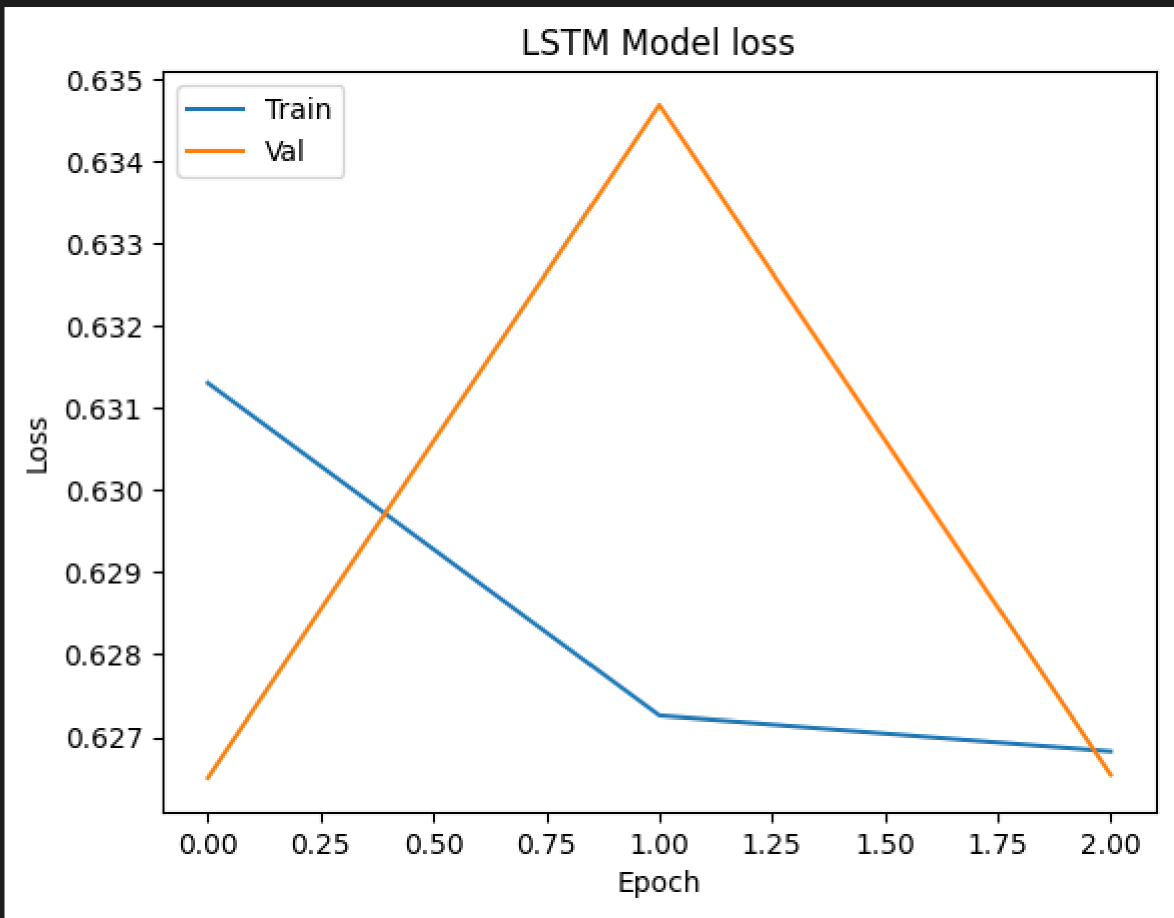
- 繪製每個epoch的training accuracy和validation accuracy的變化圖

```
#plot the trainging process for the LSTM model and show accuracy and loss
import matplotlib.pyplot as plt
plt.plot(history_lstm.history['accuracy'])
plt.plot(history_lstm.history['val_accuracy'])
plt.title('LSTM Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Val'], loc='upper left')
plt.show()
```



- 繪製每個epoch的training loss和validation loss的變化圖

```python
#plot the trainging process for the LSTM model and show accuracy and loss
plt.plot(history_lstm.history['loss'])
plt.plot(history_lstm.history['val_loss'])
plt.title('LSTM Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Val'], loc='upper left')
plt.show()
```



- 用測試集的資料評估訓練出的LSTM模型在情緒分析任務上的表現

```python
#show accuracy on test data
scores_lstm = model_lstm.evaluate(X_test, y_test)
print("Accuracy: ", scores_lstm[1])
```

```
63/63 ━━━━━━━━━━━━━━━━━━━━ 64s 1s/step - accuracy: 0.6915 - loss: 0.6185
Accuracy:  0.7014999985694885
```

- 建立結構簡單但unit更大的LSTM模型用來訓練情緒分析的能力

```
#build the LSTM model
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Embedding, LSTM, Dense
from tensorflow.keras.layers import SpatialDropout1D

(variable) model_lstm: Any ut_dim=tfidf_matrix.shape[1], output_dim=128, input_length=tfidf_matrix.shape[1]))
model_lstm.add(SpatialDropout1D(0.7))
model_lstm.add(LSTM(128, dropout=0.2, recurrent_dropout=0.2))
model_lstm.add(Dense(1, activation='sigmoid'))

model_lstm.compile(optimizer='adam', loss='binary_crossentropy', metrics=['accuracy'])
```

```
c:\Users\a0905\AppData\Local\Programs\Python\Python312\Lib\site-packages\keras\src\layers\core\embedding.py:90: UserWarning: Argument `input_length` is deprecated. Just remove it.
  warnings.warn(
```

- 印出所建構出的LSTM模型的架構

```
#show LSTM model structure
print(model_lstm.summary())
```

Model: "sequential_2"

Layer (type)	Output Shape	Param #
embedding_2 (Embedding)	(None, 29183, 128)	3,735,424
spatial_dropout1d_1 (SpatialDropout1D)	(None, 29183, 128)	0
lstm_1 (LSTM)	(None, 128)	131,584
dense_3 (Dense)	(None, 1)	129

```
Total params: 11,601,413 (44.26 MB)

Trainable params: 3,867,137 (14.75 MB)

Non-trainable params: 0 (0.00 B)

Optimizer params: 7,734,276 (29.50 MB)

None
```

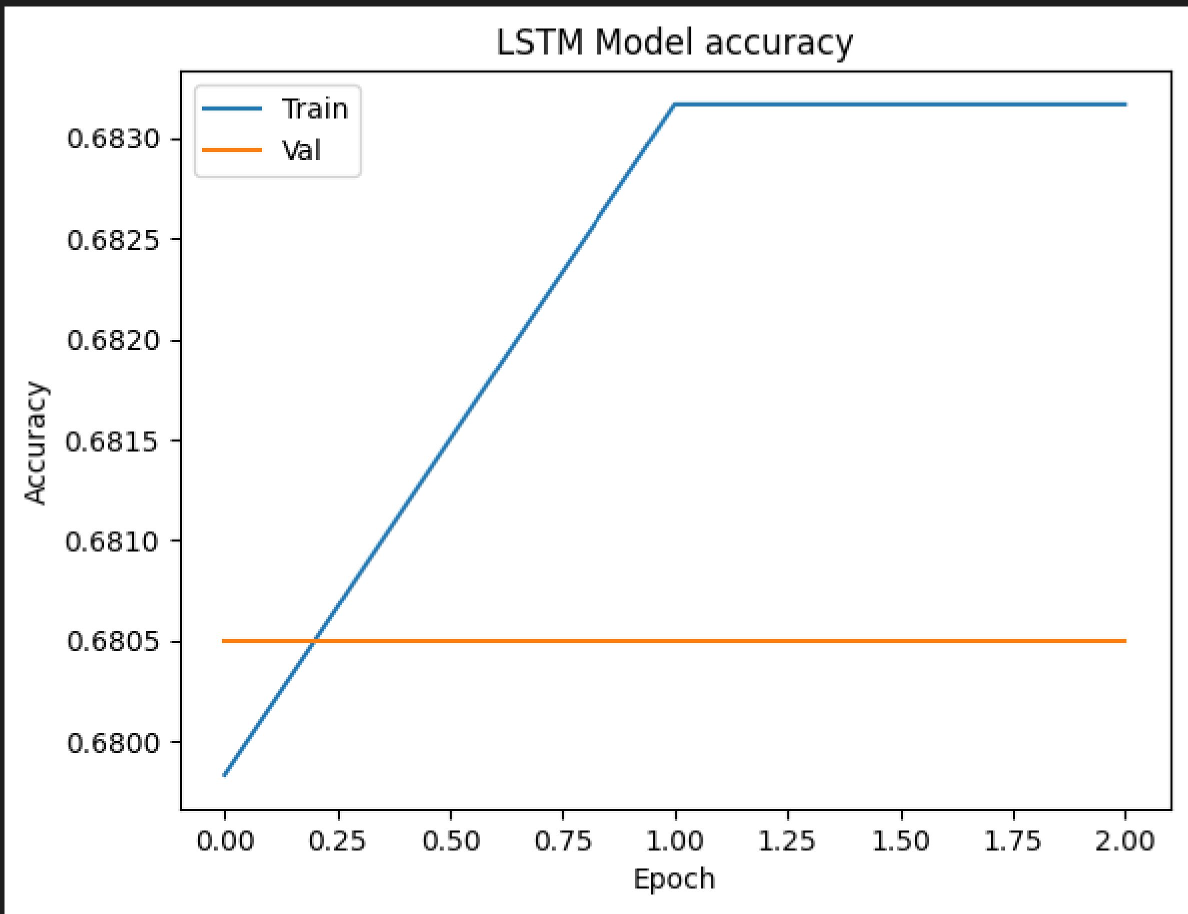
- 用建立完的LSTM模型以切割出的訓練集和測試集進行訓練

```
#train the LSTM model
history_lstm = model_lstm.fit(X_train, y_train, epochs=3, batch_size=32, validation_data=(X_val, y_val))
```

```
Epoch 1/3
188/188 ━━━━━━━━━━━━━━━━━━━━ 9814s 52s/step - accuracy: 0.6604 - loss: 0.6382 - val_accuracy: 0.6805 - val_loss: 0.6270
Epoch 2/3
188/188 ━━━━━━━━━━━━━━━━━━━━ 9748s 52s/step - accuracy: 0.6877 - loss: 0.6235 - val_accuracy: 0.6805 - val_loss: 0.6270
Epoch 3/3
188/188 ━━━━━━━━━━━━━━━━━━━━ 9758s 52s/step - accuracy: 0.6792 - loss: 0.6311 - val_accuracy: 0.6805 - val_loss: 0.6265
```

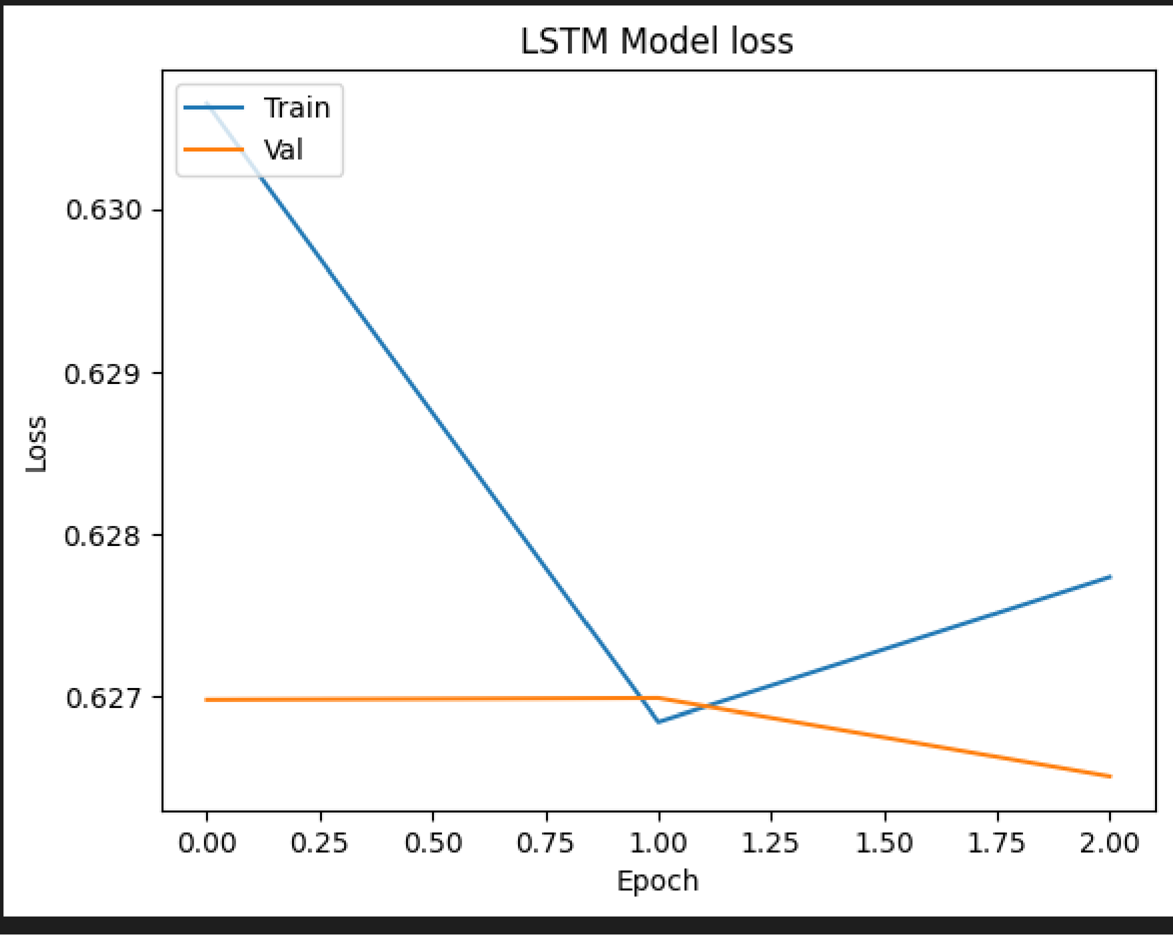
- 繪製每個epoch的training accuracy和validation accuracy的變化圖

```
#plot the trainging process for the LSTM model and show accuracy and loss
import matplotlib.pyplot as plt
plt.plot(history_lstm.history['accuracy'])
plt.plot(history_lstm.history['val_accuracy'])
plt.title('LSTM Model accuracy')
plt.ylabel('Accuracy')
plt.xlabel('Epoch')
plt.legend(['Train', 'Val'], loc='upper left')
plt.show()
```



- 繪製每個epoch的training loss和validation loss的變化圖

```
#plot the trainging process for the LSTM model and show accuracy and loss
plt.plot(history_lstm.history['loss'])
plt.plot(history_lstm.history['val_loss'])
plt.title('LSTM Model loss')
plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend(['Train', 'Val'], loc='upper left')
plt.show()
```



- 用測試集的資料評估訓練出的LSTM模型在情緒分析任務上的表現

```
#show accuracy on test data
scores_lstm = model_lstm.evaluate(X_test, y_test)
print("Accuracy: ", scores_lstm[1])
```

```
63/63 ━━━━━━━━━━━━━━━━━━━━ 118s 2s/step - accuracy: 0.6915 - loss: 0.6183
Accuracy:  0.7014999985694885
```