main

March 14, 2022

1 Used Packages

[ ]:

```
import os
import shutil
import random

import pandas as pd
import spacy
from sklearn.preprocessing import MinMaxScaler
import numpy as np
import tensorflow as tf
import tensorflow_text as text
import tensorflow_hub as hub
from official.nlp import optimization
from IPython.display import display, HTML

import matplotlib.pyplot as plt
import matplotlib
```

[ ]:

```
css = """
.output {
    display: flex;
    flex-direction: row;
}
"""

HTML('<style>{}</style>'.format(css))
```

[ ]:

```
<IPython.core.display.HTML object>
```

[ ]:

```
cmap_org = matplotlib.colors.LinearSegmentedColormap.from_list("",␣
 ↪["cornflowerblue","lime"], gamma=0.75)
cmap_new = plt.get_cmap("YlOrRd")
```

2 Model Creation

[ ]:
```
PATH = 'data'
# set this parameter if you want to train another model
TRAIN_NEW_MODEL = True
NEW_MODEL_NAME = 'imdb3'
```

2.1 Dataset

[ ]:
```
# downloading the imdb dataset (if not already done)
# removing the unnecessary unsup folder because this is a supervised ml task
if not os.path.isdir('data'):
    url = "https://ai.stanford.edu/~amaas/data/sentiment/aclImdb_v1.tar.gz"

    dataset = tf.keras.utils.get_file("aclImdb_v1", url,
                                    untar=True, cache_dir=PATH,
                                    cache_subdir='')

    shutil.rmtree('unsup')
```

[ ]:
```
# setting the directory for the training and test data
train_dir = os.path.join(PATH, 'train')
test_dir = os.path.join(PATH, 'test')
```

2.1.1 Dataset Parameters

[ ]:
```
# setting model parameters
# autotune allows the automatic setting of the number of prefetched data ahead
# of time they are requested in the learning process
AUTOTUNE = tf.data.AUTOTUNE
batch_size = 16
epochs = 1
seed = 42
init_lr = 3e-5
```

2.1.2 Splitting Dataset

[ ]:
```
# training set 80 percent of all files with 20 left for validation
raw_train_ds = tf.keras.utils.text_dataset_from_directory(
    train_dir,
    batch_size=batch_size,
    validation_split=0.2,
    subset='training',
    seed=seed)

class_names = raw_train_ds.class_names
train_ds = raw_train_ds.cache().prefetch(buffer_size=AUTOTUNE)
```

```
raw_val_ds = tf.keras.utils.text_dataset_from_directory(
    train_dir,
    batch_size=batch_size,
    validation_split=0.2,
    subset='validation',
    seed=seed)

val_ds = raw_val_ds.cache().prefetch(buffer_size=AUTOTUNE)

raw_test_ds = tf.keras.utils.text_dataset_from_directory(
    test_dir,
    batch_size=batch_size)

test_ds = raw_test_ds.cache().prefetch(buffer_size=AUTOTUNE)
```

```
Found 25000 files belonging to 2 classes.
Using 20000 files for training.
Found 25000 files belonging to 2 classes.
Using 5000 files for validation.
Found 25000 files belonging to 2 classes.
```

2.2 Model Training

[ ]:

```
if TRAIN_NEW_MODEL:
    # setting the bert encoder and preprocessor
    tfhub_handle_encoder = 'https://tfhub.dev/tensorflow/
 ↪bert_en_uncased_L-12_H-768_A-12/4'
    tfhub_handle_preprocess = 'https://tfhub.dev/tensorflow/
 ↪bert_en_uncased_preprocess/3'

    # generating the bert encoder and preprocess layer for the model
    # (save model error can be fixed by deleting temp folder)
    bert_preprocess_model = hub.KerasLayer(tfhub_handle_preprocess)
    bert_model = hub.KerasLayer(tfhub_handle_encoder)

    # function for building the classifiert model
    # text input -> preprocessing -> encode -> droput -> dense

    def build_classifier_model():
        text_input = tf.keras.layers.Input(shape=(), dtype=tf.string,␣
 ↪name='text')
        preprocessing_layer = hub.KerasLayer(tfhub_handle_preprocess,␣
 ↪name='preprocessing')
        encoder_inputs = preprocessing_layer(text_input)
        encoder = hub.KerasLayer(tfhub_handle_encoder, trainable=True,␣
 ↪name='BERT_encoder')
        outputs = encoder(encoder_inputs)
        net = outputs['pooled_output']
        net = tf.keras.layers.Dropout(0.1)(net)
        net = tf.keras.layers.Dense(1, activation=None, name='classifier')(net)
        return tf.keras.Model(text_input, net)

    # initialize classifier model
    classifier_model = build_classifier_model()

    # set loss and metric functions
    loss = tf.keras.losses.BinaryCrossentropy(from_logits=True)
    metrics = tf.metrics.BinaryAccuracy()

    # create model hyperparameter optimizer
    steps_per_epoch = tf.data.experimental.cardinality(train_ds).numpy()
    num_train_steps = steps_per_epoch * epochs
    num_warmup_steps = int(0.1*num_train_steps)

    optimizer = optimization.create_optimizer(init_lr=init_lr,
                                            num_train_steps=num_train_steps,
                                            num_warmup_steps=num_warmup_steps,
                                            optimizer_type='adamw')

    # early stopping
    # early_stopping = tf.keras.callbacks.EarlyStopping(monitor='val_loss')

    # compile the model
    classifier_model.compile(optimizer=optimizer,
                            loss=loss,
                            metrics=metrics)

    # train the model
    history = classifier_model.fit(x=train_ds,
                                validation_data=val_ds,
                                epochs=epochs)
```

```
1250/1250 [==============================] - 390s 301ms/step - loss: 0.3586 -
binary_accuracy: 0.8336 - val_loss: 0.2872 - val_binary_accuracy: 0.8800
```

[ ]:

```
if TRAIN_NEW_MODEL:
    loss, accuracy = classifier_model.evaluate(test_ds)
```

```
1563/1563 [==============================] - 172s 110ms/step - loss: 0.2773 -
binary_accuracy: 0.8805
```

[ ]:

```
if TRAIN_NEW_MODEL:
    saved_model_path = f'./models/{NEW_MODEL_NAME}_bert'
    classifier_model.save(saved_model_path, include_optimizer=False)
```

```
WARNING:absl:Found untraced functions such as restored_function_body,
restored_function_body, restored_function_body, restored_function_body,
restored_function_body while saving (showing 5 of 915). These functions will not
be directly callable after loading.

INFO:tensorflow:Assets written to: ./models/imdb3_bert\assets

INFO:tensorflow:Assets written to: ./models/imdb3_bert\assets
```

3 Loading the Model and working with it

```
[ ]: if not TRAIN_NEW_MODEL:
         saved_model_path = f'models/{os.listdir("models")[1]}'
         model = tf.keras.models.load_model(saved_model_path, compile=False)
     else:
         model = classifier_model
```

3.0.1 Retrieve Complete Test Data

```
[ ]: test_data_unbatched = list(test_ds.unbatch().as_numpy_iterator())
```

3.0.2 Select Random Pair

```
[ ]: rand_ind = random.randint(0, len(test_data_unbatched))
     rand_sen_label_pair = test_data_unbatched[rand_ind]
     rand_sen_label_pair[0]
     # rand_sen_label_pair = ('Just a boring and uninspired film filled with bad␣
      ↪acting.', 0)
```

```
[ ]: b"What looks like a ho-hum Porky's rip-off turns out to be quite a touching film
     about being young and in love.<br /><br />The story concerns three friends,
     Gary, Ricky and David, who spend their after school hours looking for sex. When
     a new girl arrives in town Gary falls head over heels in love with her.<br /><br
     />The film goes from being a sleazy sex film to an examination of teenage
     insecurities. It is funny and sad at the same time. It never completely gives
     into that love story formula that seems prominent in every movie made. You know
     the guy meets girl, guy loses girl, guy gets girl back in the final frame
     formula. That formula is tossed aside after guy meets girl. Maybe that is why I
     liked the film so much.<br /><br />The soundtrack is especially good and the
     ending is a definite tear jerker. It also might be one of the most realistic
     endings I've ever seen in a love story.<br /><br />"
```

3.0.3 Function for Text Classification

```
[ ]: def classify_text(model, text, parent_ind=None, child_ind=None):
         '''
         Function to predict a given text given a model.
         The predicted score is furthermore transformed into the corresponding
         label.
```

```
    '''
    score = tf.sigmoid(model(tf.constant([text])))[0][0].numpy()
    pred_label = np.where(score > 0.5, 1, 0).item()

    return (score, pred_label, parent_ind, child_ind)
```

3.0.4 Predict Random Pair Label and Score

[ ]:

```
org_text_pred = classify_text(model, rand_sen_label_pair[0])
print(f'Predicted Label: {org_text_pred[1]} \nScore: {org_text_pred[0]} \nReal Label: {rand_sen_label_pair[1]}')
```

```
Predicted Label: 1
Score: 0.9611169099807739
Real Label: 1
```

3.0.5 Dependecy Parsing

[ ]:

```
depend_parser = spacy.load('en_core_web_sm')
```

[ ]:

```
parsed_text = depend_parser(str(rand_sen_label_pair[0]))
sentence_spans = list(parsed_text.sents)[0]
```

[ ]:

```
spacy.displacy.render(sentence_spans, jupyter=True, options={"compact": True})
```

```
<IPython.core.display.HTML object>
```

3.0.6 Functions for Text Generation

[ ]:

```
def leave_n_out(text):
    '''
    Function for generating texts from an original text, where every
    text is missing a different parent-child-word-combination of
    the original text.

    Go over all words, if a word has children, then for every parent-child-pair
    return a text with both removed.
    '''
    leave_n_out_texts = []

    for parent_to_remove in text:
        child_list = [child for child in parent_to_remove.children]

        if child_list:
            for child_to_remove in child_list:
                new_text = []
                for word in text:
                    if (word.i != parent_to_remove.i and
                        word.i != child_to_remove.i):
                            new_text.append(word.text)

                leave_n_out_texts.append(
                    (" ".join(new_text), parent_to_remove.i, child_to_remove.i))

    return leave_n_out_texts


def leave_one_out(text):
    '''
    Function for generating texts from an original text, where
    every text is missing one different word of the original text.
    '''
    leave_one_out_texts = []

    for word_to_remove in text:
        new_text = []

        for word in text:
            if word_to_remove.i != word.i:
                new_text.append(word.text)

        leave_one_out_texts.append(
            (" ".join(new_text), word_to_remove.i, None))

    return leave_one_out_texts

def leave_childs_out(text):
    '''
    Function for generating texts from an original text, where
    every text is missing a prent word and all of it's children.
    '''
    leave_childs_out_texts = []

    for word_to_remove in text:
        new_text = []
        child_ids = [child.i for child in word_to_remove.children]

        for word in text:
            if word_to_remove.i != word.i and word.i not in child_ids:
                new_text.append(word.text)

        leave_childs_out_texts.append(
            (" ".join(new_text), word_to_remove.i, child_ids))
    return leave_childs_out_texts

def leave_n_ancestors_out(text):
    '''
    Function for generating texts from an original text, where every
    text is missing a different parent-ancestor-word-combination of
    the original text.

    Go over all words, if a word has ancestors, then for every␣
 ↪parent-ancestor-pair
    return a text with both removed.
    '''
    leave_n_out_texts = []

    for parent_to_remove in text:
        ancest_list = [ancest for ancest in parent_to_remove.ancestors]

        if ancest_list:
            for ancest_to_remove in ancest_list:
                new_text = []

                for word in text:
                    if (word.i != parent_to_remove.i and
                        word.i != ancest_to_remove.i):
                            new_text.append(word.text)

                leave_n_out_texts.append(
                    (" ".join(new_text), parent_to_remove.i, ancest_to_remove.
 ↪i))

    return leave_n_out_texts
```

3.0.7 Functions for Further Processing

[ ]:
```
def drop_unimportant_words(df, label, org_score):
    '''
    Function to drop unimportant words.
    An unimportant word is one which increases
    the difference of the classificaion with out it vs. with it .

    For example: "The movie was very good."
    Score: 0.9
    Score without "the": 0.95

    "The" is unimportant, because the classification without it increases.
    '''
    if label == 1:
        df = df.drop(df.index[df['Score'] >= org_score] )
    else:
        df = df.drop(df.index[df['Score'] <= org_score] )

def calc_score_diff(df, label, org_score):
    '''
    Function to calculate the score differences of the original text to
    those with certain words removed.
    '''
    if label == 1:
        df['Score Difference'] = org_score - df['Score']
    else:
        df['Score Difference'] = df['Score'] - org_score

def create_df(texts):
    '''
    Function to create a dataframe out of a given list of texts.
    The constructed dataframe consists of four columns:
    Score, Predicted Label, Parent Index and Child Index.

    The values for all columns come from the classify_text function.
    '''

    df = pd.DataFrame(
        [classify_text(model, text[0], text[1], text[2]) for text in texts],
        columns=['Score',
                 'Predicted Label',
                 'Parent Index',
                 'Child Index'])

    return df

def linearize_score_diff(df, choose_best_diff=False):
    '''
    Function to linearize the score differences in a given dataframe.
    If choose_best_score flag is set, the best difference for every
    token is choosen.

    For example:
    If the word "good" is a child of the word "movie" and the word "story"
    the best score difference of both pairs is choosen. If "good" happens
    to be a parent with children itself, all those possible pairs are
    considered either for best difference.
    '''
    if choose_best_diff:
        df_copy = df.copy()
        df_copy[['Child Index', 'Parent Index']
                ] = df[['Parent Index', 'Child Index']]
        df = pd.concat([df, df_copy]).reset_index(drop=True)
        df = df.loc[df.groupby(['Parent Index'])[
            "Score Difference"].idxmax()]

    df['Score Difference'] = MinMaxScaler(
    ).fit_transform(df[['Score Difference']])

    df.drop(
        ["Score", "Predicted Label", "Child Index"],
        inplace=True, axis=1)

    df = df.sort_values(by=['Score Difference'])

    df.rename(columns={"Parent Index": "Token Index"}, inplace=True)

    return df
```

3.0.8 Functions for Visualization

[ ]:
```
def vis_text(df):
    '''
    Function which creates a plt plot without axis of a given text
    with given word importances.

    It draws all words in a row, creating a new one whenever the current
    row is to full. Words are colored given the corresponding importance
    in the dataframe.

    If a word is not given in the dataframe, for example if it was removed
    due to not contributing to the classification, it is colored white.
    '''
    start_x = 20
    start_y = 500
    end = 1200
    whitespace = 8

    figure = plt.figure(figsize=(20, 10))
    rend = figure.canvas.get_renderer()

    for token in parsed_text:
        if df.loc[df["Token Index"] == token.i, 'Score Difference'].values.size␣
↪> 0:
            col = cmap_org(df.loc[df["Token Index"] == token.i, 'Score␣
↪Difference'].values[0])
        else:
            col = "white"
        bbox = dict(boxstyle="round,pad=0.3", fc=col, ec="white")

        txt = plt.text(start_x, start_y, str(token), bbox=bbox, transform=None)

        bb = txt.get_window_extent(renderer=rend)

        start_x = bb.width + start_x + whitespace

        if start_x >= end:
            start_x = 20
            start_y -= 20

    plt.axis("off")
    plt.show()
```

3.1 Generating New Texts

[ ]:
```
# Original Experiments
new_texts_lno = leave_n_out(parsed_text)
new_texts_loo = leave_one_out(parsed_text)
```

3.2 Generating DataFrames

[ ]:
```
df_lno = create_df(new_texts_lno)
df_loo = create_df(new_texts_loo)

display(df_lno)
display(df_loo)
```

```
        Score  Predicted Label  Parent Index  Child Index
0    0.959754                1             1            0
1    0.947363                1             1            2
2    0.862692                1             1           12
3    0.958654                1             1           26
4    0.953679                1             1           27
..        …              …           …          …
170  0.955708                1           178          176
171  0.955708                1           178          177
172  0.955708                1           178          179
173  0.955708                1           179          181
174  0.955708                1           181          180

[175 rows x 4 columns]

        Score  Predicted Label  Parent Index Child Index
0    0.951701                1             0        None
1    0.946163                1             1        None
```

```
2    0.954155                1             2        None
3    0.951021                1             3        None
4    0.950034                1             4        None
..        …               …           …         …
182  0.955708                1           182        None
183  0.955708                1           183        None
184  0.955708                1           184        None
185  0.955708                1           185        None
186  0.955708                1           186        None

[187 rows x 4 columns]
```

3.3 Dropping Unimportant Words

[ ]:
```
drop_unimportant_words(df_lno, org_text_pred[1], org_text_pred[0])
drop_unimportant_words(df_loo, org_text_pred[1], org_text_pred[0])
```

3.4 Calculating Score Differences

[ ]:
```
calc_score_diff(df_lno, org_text_pred[1], org_text_pred[0])
calc_score_diff(df_loo, org_text_pred[1], org_text_pred[0])
```

3.5 Linearizing Score Difference

[ ]:
```
df_lno = linearize_score_diff(df_lno, choose_best_diff=True)
df_loo = linearize_score_diff(df_loo)

display(df_lno)
display(df_loo)
```

```
     Token Index  Score Difference
262           93          0.000000
238           67          0.018510
245           72          0.022629
268           97          0.038391
237           64          0.048408
..           …                 …
186            6          0.617579
187            7          0.691251
12            12          0.691251
20            19          1.000000
195           18          1.000000

[186 rows x 2 columns]
```

```
    Token Index  Score Difference
68           68          0.000000
72           72          0.002065
```

```
26           26        0.018727
27           27        0.026063
65           65        0.031610
..          …              …
85           85        0.290025
95           95        0.295534
89           89        0.375238
18           18        0.550888
12           12        1.000000

[187 rows x 2 columns]
```

3.5.1 Additional Experiments

[ ]:

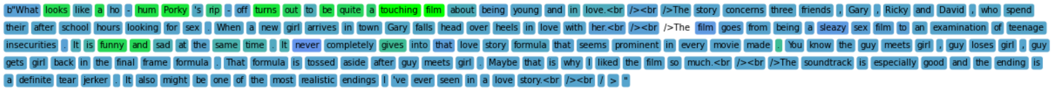
```
# Removing the Parent and all Children before Classification
new_texts_lco = leave_childs_out(parsed_text)
df_lco = create_df(new_texts_lco)
drop_unimportant_words(df_lco, org_text_pred[1], org_text_pred[0])
calc_score_diff(df_lco, org_text_pred[1], org_text_pred[0])
df_lco = df_lco.explode('Child Index')
df_lco = linearize_score_diff(df_lco, choose_best_diff=True)

# Removing the Parent and all Ancesters (implicite Connections) before␣
 ↪Classification
new_texts_lnao = leave_n_ancestors_out(parsed_text)
df_lnao = create_df(new_texts_lnao)
drop_unimportant_words(df_lnao, org_text_pred[1], org_text_pred[0])
calc_score_diff(df_lnao, org_text_pred[1], org_text_pred[0])
df_lnao = linearize_score_diff(df_lnao, choose_best_diff=True)
```

3.5.2 Visualize Texts

[ ]:

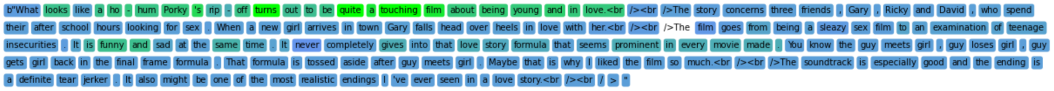
```
print('Leave n out:')
vis_text(df_lno)
print('Leave all ancestors out')
vis_text(df_lnao)
print('Leave children out')
vis_text(df_lco)
print('Leave one out:')
vis_text(df_loo)
```

```
Leave n out:
```



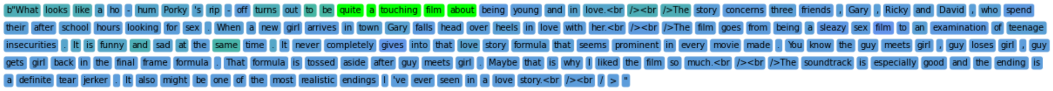
b"What looks like a ho - hum Porky 's rip - off turns out to be quite a touching film about being young and in love.<br /><br />The story concerns three friends , Gary , Ricky and David , who spend
their after school hours looking for sex . When a new girl arrives in town Gary falls head over heels in love with her.<br /><br />The film goes from being a sleazy sex film to an examination of teenage
insecurities . It is funny and sad at the same time . It never completely gives into that love story formula that seems prominent in every movie made . You know the guy meets girl , guy loses girl , guy
gets girl back in the final frame formula . That formula is tossed aside after guy meets girl . Maybe that is why I liked the film so much.<br /><br />The soundtrack is especially good and the ending is
a definite tear jerker . It also might be one of the most realistic endings I 've ever seen in a love story.<br /><br / > "

Leave all ancestors out



b"What looks like a ho - hum Porky 's rip - off turns out to be quite a touching film about being young and in love.<br /><br />The story concerns three friends , Gary , Ricky and David , who spend
their after school hours looking for sex . When a new girl arrives in town Gary falls head over heels in love with her.<br /><br />The film goes from being a sleazy sex film to an examination of teenage
insecurities . It is funny and sad at the same time . It never completely gives into that love story formula that seems prominent in every movie made . You know the guy meets girl , guy loses girl , guy
gets girl back in the final frame formula . That formula is tossed aside after guy meets girl . Maybe that is why I liked the film so much.<br /><br />The soundtrack is especially good and the ending is
a definite tear jerker . It also might be one of the most realistic endings I 've ever seen in a love story.<br /><br / > "

Leave children out



b"What looks like a ho - hum Porky 's rip - off turns out to be quite a touching film about being young and in love.<br /><br />The story concerns three friends , Gary , Ricky and David , who spend
their after school hours looking for sex . When a new girl arrives in town Gary falls head over heels in love with her.<br /><br />The film goes from being a sleazy sex film to an examination of teenage
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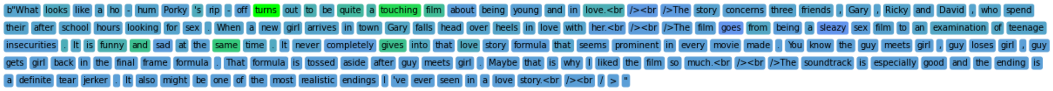
a definite tear jerker . It also might be one of the most realistic endings I 've ever seen in a love story.<br /><br / > "

Leave one out:



b"What looks like a ho - hum Porky 's rip - off turns out to be quite a touching film about being young and in love.<br /><br />The story concerns three friends , Gary , Ricky and David , who spend
their after school hours looking for sex . When a new girl arrives in town Gary falls head over heels in love with her.<br /><br />The film goes from being a sleazy sex film to an examination of teenage
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gets girl back in the final frame formula . That formula is tossed aside after guy meets girl . Maybe that is why I liked the film so much.<br /><br />The soundtrack is especially good and the ending is
a definite tear jerker . It also might be one of the most realistic endings I 've ever seen in a love story.<br /><br / > "