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1 Assignment 7

CS4172 Machine Learning Lab

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1.1 Task 1

Download and preprocess the sentiment analysis dataset from https://www.kaggle.com/snap/amazon-fine-food-reviews. Download the Glove word vectors from http://nlp.stanford.edu/data/glove.6B.zip and extract the 100-dimensional file (glove.6B.100d.txt) from the zipped folder.

1.2 Task 2

Preprocess the review dataset by considering the column "review score" >3 as positive reviews and others as negative reviews. For training on local machine considers 5000 positive and negative reviews each for the training dataset.

Consider 2000 reviews for the test dataset and validation dataset each. Strip the length of each review sentence (number of words) according to your computation availability.

[2]:
```
import tensorflow as tf
import os
os.environ["TF_CPP_MIN_LOG_LEVEL"] = "3"  # ignore CUDA messages

# Hide GPU from visible devices
tf.config.set_visible_devices([], 'GPU')
```

```
---------------------------------------------------------------------------
ModuleNotFoundError                       Traceback (most recent call last)
Cell In[2], line 1
----> 1 import tensorflow as tf
      2 import os
      3 os.environ["TF_CPP_MIN_LOG_LEVEL"] = "3"  # ignore CUDA messages

ModuleNotFoundError: No module named 'tensorflow'
```

[ ]:
```
AMAZON_REVIEW_PATH = "./../ML_DRIVE/Assign_7/Amazon Review/Reviews.csv"
GLOVE_FILE_PATH = "./../ML_DRIVE/Assign_7/glove.6B/glove.6B.100d.txt"

# https://keras.io/examples/nlp/pretrained_word_embeddings/
```

[ ]:
```
import pandas as pd

review_df = pd.read_csv(AMAZON_REVIEW_PATH)
review_df.head()
```

[ ]:
```
   Id   ProductId          UserId                      ProfileName  \
0   1  B001E4KFG0  A3SGXH7AUHU8GW                       delmartian
1   2  B00813GRG4  A1D87F6ZCVE5NK                           dll pa
2   3  B000LQOCH0   ABXLMWJIXXAIN  Natalia Corres "Natalia Corres"
3   4  B000UA0QIQ  A395BORC6FGVXV                             Karl
4   5  B006K2ZZ7K  A1UQRSCLF8GW1T    Michael D. Bigham "M. Wassir"

   HelpfulnessNumerator  HelpfulnessDenominator  Score        Time  \
0                     1                       1      5  1303862400
1                     0                       0      1  1346976000
2                     1                       1      4  1219017600
3                     3                       3      2  1307923200
4                     0                       0      5  1350777600

                Summary                                                Text
0  Good Quality Dog Food  I have bought several of the Vitality canned d…
1      Not as Advertised  Product arrived labeled as Jumbo Salted Peanut…
2  "Delight" says it all  This is a confection that has been around a fe…
3         Cough Medicine  If you are looking for the secret ingredient i…
4            Great taffy  Great taffy at a great price.  There was a wid…
```

[ ]:
```
review_df.columns
```

[ ]:
```
Index(['Id', 'ProductId', 'UserId', 'ProfileName', 'HelpfulnessNumerator',
       'HelpfulnessDenominator', 'Score', 'Time', 'Summary', 'Text'],
      dtype='object')
```

[ ]:
```
columns_to_keep = ['Score', 'Summary', 'Text']

review_df = review_df[columns_to_keep]

review_df.iloc[0:1]
```

[ ]:
```
   Score                Summary  \
0      5  Good Quality Dog Food

                                                Text
```

```
0  I have bought several of the Vitality canned d…
```

[ ]:
```
# merge summary and text (summary in front)

review_df['full_review'] = review_df['Summary'] + ' ' + review_df['Text']
review_df = review_df.drop(['Summary', 'Text'], axis=1)

review_df.iloc[0:1]
```

[ ]:
```
   Score                                        full_review
0      5  Good Quality Dog Food I have bought several of…
```

[ ]:
```
# 1 is true, 0 is false
import numpy as np
review_df['review score'] = np.where(review_df.Score > 3, 1, 0)
review_df = review_df.drop(['Score'], axis=1)
review_df
```

[ ]:
```
                                             full_review  review score
0       Good Quality Dog Food I have bought several of…             1
1       Not as Advertised Product arrived labeled as J…             0
2       "Delight" says it all This is a confection tha…             1
3       Cough Medicine If you are looking for the secr…             0
4       Great taffy Great taffy at a great price.  The…             1
…                                                     …           …
568449  Will not do without Great for sesame chicken…              1
568450  disappointed I'm disappointed with the flavor…              0
568451  Perfect for our maltipoo These stars are small…             1
568452  Favorite Training and reward treat These are t…             1
568453  Great Honey I am very satisfied ,product is as…             1

[568454 rows x 2 columns]
```

[ ]:
```
# taking 2000 samples for test and validation dataset

test_df = review_df.sample(2000, random_state=100)
val_df = review_df.sample(2000, random_state=100)
review_df = review_df.drop(test_df.index.tolist() + val_df.index.tolist())
```

[ ]:
```
# review df does not contain the rows in test_df and val_df
review_df
```

[ ]:
```
                                             full_review  review score
0       Good Quality Dog Food I have bought several of…             1
1       Not as Advertised Product arrived labeled as J…             0
2       "Delight" says it all This is a confection tha…             1
3       Cough Medicine If you are looking for the secr…             0
```

```
4       Great taffy Great taffy at a great price.  The…             1
…                                                    …           …
568449  Will not do without Great for sesame chicken…               1
568450  disappointed I'm disappointed with the flavor…              0
568451  Perfect for our maltipoo These stars are small…             1
568452  Favorite Training and reward treat These are t…             1
568453  Great Honey I am very satisfied ,product is as…             1

[566454 rows x 2 columns]
```

[ ]:
```
true_df = review_df[review_df['review score'] == 1]
false_df = review_df[review_df['review score'] == 0]

true_df = true_df.sample(5000, random_state=100)
false_df = false_df.sample(5000, random_state=100)

train_df = pd.concat([true_df, false_df]).sort_index()

train_df
```

[ ]:
```
                                              full_review  review score
29      The Best Hot Sauce in the World I don't know i…             1
76      Good These looked like a perfect snack to thro…             1
112     My every day green tea I have been drinking Ro…             1
131     Not for me I must be a bit of a wuss, because …             0
174     Great but not as good as it was back in the da…             1
…                                                    …           …
568124  The Perfect K-cup, 40 Years in the Making Firs…             1
568128  Good, but not Great I live near Seattle and ha…             0
568206  Little peppers - BIG TASTE! 3/23/11  South New…             1
568413  premium edge cat food My cats don't like it. w…             0
568427  The search has ended! I had been looking for t…             1

[10000 rows x 2 columns]
```

[ ]:
```
# using TextVectorization to index the vocabulary
from tensorflow.keras.layers import TextVectorization

vectorizer = TextVectorization(output_sequence_length=100)
vectorizer.adapt(train_df['full_review'].to_list())
```

[ ]:
```
# Note the first two are default
# "empty" and "unknown" vocabulary word
vectorizer.get_vocabulary()[:5]
```

[ ]:
```
['', '[UNK]', 'the', 'i', 'and']
```

[ ]:
```
voc = vectorizer.get_vocabulary()
word_index = dict(zip(voc, range(len(voc))))

# Now we have the vocabulary encoding of all the words
# in the training dataset in the vectorizer
```

[ ]:
```
# converting the glove file,
# where every line is "word coefs" into a dict

import numpy as np

embedding_index = {}

with open(GLOVE_FILE_PATH) as f:
    for line in f:
        word, coefs = line.split(maxsplit=1)
        coefs = np.fromstring(coefs, dtype=float, sep=" ")
        embedding_index[word] = coefs

print(f"Found {len(embedding_index)} word vectors.")
```

```
Found 400000 word vectors.
```

[ ]:
```
# now converting it into an embedding layer for using it directly on model
# for more info about embedding layer: https://medium.com/analytics-vidhya/
 ↪understanding-embedding-layer-in-keras-bbe3ff1327ce#:~:
 ↪text=Embedding%20layer%20enables%20us%20to,way%20along%20with%20reduced%20dimensions.
 ↪

num_tokens = len(voc) + 2  # +2 for "empty" and "unknown"
embedding_dim = 100  # cause using glove 100 model
hits = 0  # number of words in vocabulary that are also in the glove map
misses = 0  # number of words in vocabulary that are not in the glove map

# Prepare embedding matrix
# embedding_matrix[i] will be the 100 dimension list
# i is the index made using vocabulary using the vectorizer
embedding_matrix = np.zeros((num_tokens, embedding_dim))

for word, i in word_index.items():
    embedding_vector = embedding_index.get(word)

    if embedding_vector is not None:
        # Words not found in embedding index will be all-zeros.
        # This includes the representation for "padding" and "OOV"
        embedding_matrix[i] = embedding_vector
        hits += 1
```

```
    else:
        misses += 1

print(f"Converted {hits} word, {misses} misses")
```

```
Converted 18119 word, 10389 misses
```

[ ]:
```
import tensorflow.keras as keras
from tensorflow.keras.layers import Embedding

glove_embedding = Embedding(
    num_tokens,
    embedding_dim,
    embeddings_initializer=keras.initializers.Constant(embedding_matrix),
    trainable=False,
)
```

[ ]:
```
# Now the basic idea
# word -> encoded number using vectorizer ->
# convert to 100d vector using embedding layer -> neural network
```

[ ]:
```
x_train = vectorizer(
    np.array(
        [[s] for s in train_df['full_review'].tolist()]
    )
).numpy()

x_val = vectorizer(
    np.array(
        [[s] for s in val_df['full_review'].tolist()]
    )
).numpy()

x_test = vectorizer(
    np.array(
        [[s] for s in test_df['full_review'].tolist()]
    )
).numpy()
```

[ ]:
```
from tensorflow.keras.utils import to_categorical


y_train = to_categorical(train_df['review score'].tolist())
y_val = to_categorical(val_df['review score'].tolist())
y_test = to_categorical(test_df['review score'].tolist())
```

[ ]:
```
from tensorflow.keras import Sequential
from tensorflow.keras.layers import \
    Dense, Input, LSTM, GRU, Bidirectional, Dropout
from tensorflow.keras.callbacks import EarlyStopping
import matplotlib.pyplot as plt
import time
from keras.utils.layer_utils import count_params

# set figure size
plt.rcParams['figure.figsize'] = [12, 5]


def train_model(
    x_train,
    y_train,
    x_val,
    y_val,
    rnn_type: str,
    num_rnn_layers: int,
    rnn_layer_unit: int,
    embedding_layer_type: str,
    bidirectional: bool,
    rnn_drop_rate: float,
    drop_rate: float,
    num_epochs: int = 30,
    give_model=False
):
    model = Sequential()
    model.add(Input(shape=(None, ), dtype="int64"))

    if embedding_layer_type == 'glove':
        model.add(glove_embedding)
    elif embedding_layer_type == 'trainable_embedding':
        model.add(Embedding(num_tokens, embedding_dim))
    elif embedding_layer_type == 'one_hot':
        model.add(
            Embedding(np.ones((num_tokens, num_tokens)), trainable=False)
        )

    else:
        raise Exception('Error: undefined embedding_layer_type')

    # return_sequences=True does not reduce the Dimension Count of Output
    for _ in range(0, num_rnn_layers-1):
        if rnn_drop_rate != 0:
            model.add(Dropout(rnn_drop_rate))
```

```
        if bidirectional:
            if rnn_type == 'lstm':
                model.add(Bidirectional(
                    LSTM(rnn_layer_unit, activation='relu',
                         return_sequences=True)
                ))
            elif rnn_type == 'gru':
                model.add(Bidirectional(
                    GRU(rnn_layer_unit, activation='relu',
                        return_sequences=True)
                ))
            else:
                raise Exception('Error: undefined rnn_type')
        else:
            if rnn_type == 'lstm':
                model.add(
                    LSTM(rnn_layer_unit, activation='relu',
                         return_sequences=True)
                )
            elif rnn_type == 'gru':
                model.add(
                    GRU(rnn_layer_unit, activation='relu',
                        return_sequences=True)
                )
            else:
                raise Exception('Error: undefined rnn_type')

    if rnn_drop_rate != 0:
        model.add(Dropout(rnn_drop_rate))

    if bidirectional:
        if rnn_type == 'lstm':
            model.add(Bidirectional(
                LSTM(rnn_layer_unit, activation='relu')
            ))
        elif rnn_type == 'gru':
            model.add(Bidirectional(
                GRU(rnn_layer_unit, activation='relu')
            ))
        else:
            raise Exception('Error: undefined rnn_type')
    else:
        if rnn_type == 'lstm':
            model.add(LSTM(rnn_layer_unit, activation='relu'))
        elif rnn_type == 'gru':
            model.add(GRU(rnn_layer_unit, activation='relu'))
        else:
```

```
            raise Exception('Error: undefined rnn_type')

    if drop_rate != 0:
        model.add(Dropout(drop_rate))

    model.add(Dense(100, activation='relu'))
    model.add(Dense(2, activation="softmax"))
    model.summary()
    model.compile(
        loss="categorical_crossentropy", metrics=["accuracy"]
    )

    callback = [
        EarlyStopping(
            monitor='val_loss',
            patience=10,
            restore_best_weights=True
        )
    ]

    start_time = time.time()
    history = model.fit(
        x_train,
        y_train,
        epochs=num_epochs,
        validation_data=(x_val, y_val),
        callbacks=callback,
        verbose=0
    )

    if give_model:
        return model

    train_time = time.time() - start_time

    start_time = time.time()
    val_loss, val_acc = model.evaluate(x_val, y_val, verbose=0)
    infer_time = time.time() - start_time

    num_param = count_params(model.trainable_weights)

    plt.plot(
        history.history['loss'],
        label=f"{num_rnn_layers} layers;{rnn_type};{rnn_layer_unit} units;
↪{embedding_layer_type} embed;bidirec {bidirectional};drop {drop_rate};
↪rnn_drop {rnn_drop_rate}"
    )
```

```
    return num_param, val_loss, val_acc, train_time, infer_time
```

[ ]:
```
result_df = pd.DataFrame(columns=[
    'RNN Type',
    'RNN Layer',
    'RNN Size',
    'Embedding Layer',
    'Bidirectional',
    'RNN Dropout Rate',
    'Dropout Rate',
    'Num Params',
    'Val Loss',
    'Val Accuracy',
    'Train Time (s)',
    'Infer Time (s)'
])
```

1.3 Task 3

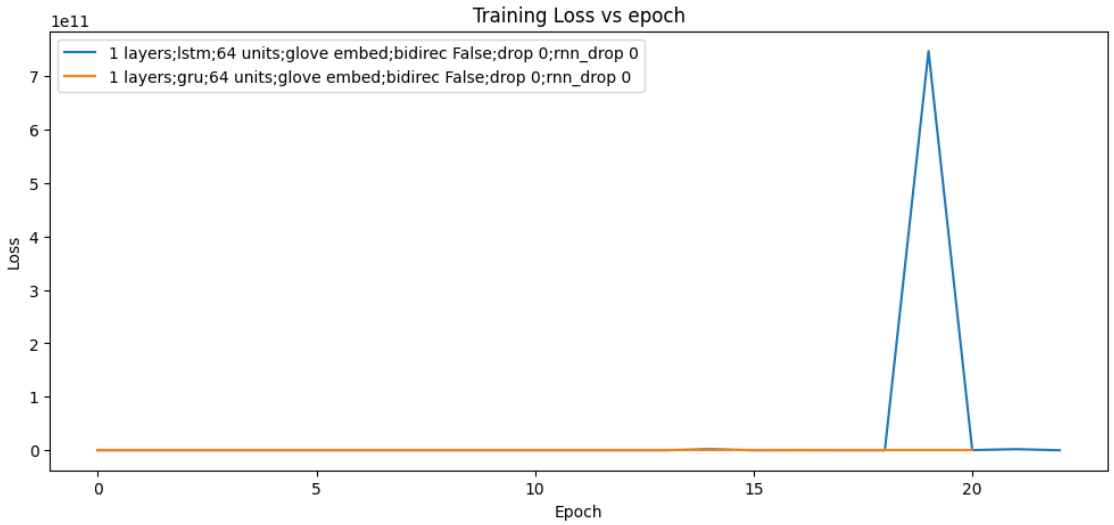
Train RNN model with the FC layer applied in the final hidden layer output using the following parameter

Sr. No:	RNN	RNN Layer	RNN Size	Activation	FC Layer	Embedding Layer
1	LSTM	1	64	Relu	1	Glove
2	GRU	1	64	Relu	1	Glove

[ ]:
```
rnn_types = ['lstm', 'gru']
num_rnn_layers = 1
rnn_layer_unit = 64
embedding_layer_type = 'glove'
bidirectional = False
rnn_drop_rate = 0
drop_rate = 0


for rnn_type in rnn_types:
    num_param, val_loss, val_acc, train_time, infer_time = train_model(
        x_train,
        y_train,
        x_val,
        y_val,
        rnn_type=rnn_type,
        num_rnn_layers=num_rnn_layers,
        rnn_layer_unit=rnn_layer_unit,
        embedding_layer_type=embedding_layer_type,
```

```
        bidirectional=bidirectional,
        rnn_drop_rate=rnn_drop_rate,
        drop_rate=drop_rate
    )

    print(f"{num_rnn_layers} layers;{rnn_type};{rnn_layer_unit} units;
↪{embedding_layer_type} embed;bidirec {bidirectional};drop {drop_rate};
↪rnn_drop {rnn_drop_rate} => {num_param} Params;val_loss={val_loss};
↪val_acc={round(val_acc,2)};train_time={round(train_time,2)}s;
↪infer_time={round(infer_time,2)}s")

    result_df.loc[len(result_df.index)] = [
        rnn_type,
        num_rnn_layers,
        rnn_layer_unit,
        embedding_layer_type,
        bidirectional,
        rnn_drop_rate,
        drop_rate,
        num_param,
        val_loss,
        val_acc,
        train_time,
        infer_time
    ]

plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend()
plt.title(f'Training Loss vs epoch')
plt.show()
```

```
1 layers;lstm;64 units;glove embed;bidirec False;drop 0;rnn_drop 0 => 48942 Para
ms;val_loss=0.5695447325706482;val_acc=0.73;train_time=240.92s;infer_time=0.47s
1 layers;gru;64 units;glove embed;bidirec False;drop 0;rnn_drop 0 => 38574 Param
s;val_loss=0.28342491388320923;val_acc=0.88;train_time=185.9s;infer_time=0.51s
```



[ ]:
```
result_df
```

[ ]:
```
  RNN Type  RNN Layer  RNN Size Embedding Layer  Bidirectional  \
0     lstm          1        64           glove          False
1      gru          1        64           glove          False

   RNN Dropout Rate  Dropout Rate  Num Params  Val Loss  Val Accuracy  \
0                 0             0       48942  0.569545        0.7310
1                 0             0       38574  0.283425        0.8775

   Train Time (s)  Infer Time (s)
0      240.921910        0.466113
1      185.895412        0.512385
```

[ ]:
```
best_rnn_type = result_df.sort_values(
    by=['Val Accuracy', 'Val Loss'],
    ascending=[False, True]
)['RNN Type'].iloc[0]

best_rnn_type
```

[ ]:
```
'gru'
```

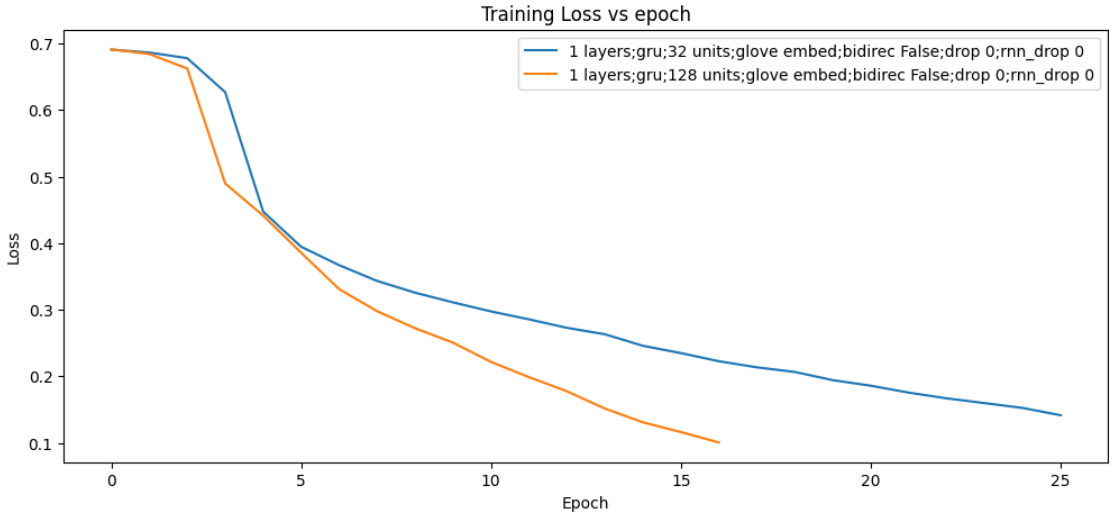
1.4 Task 4

For the best model above vary the size of RNN : [32,128]

[ ]:
```
num_rnn_layers = 1
rnn_layer_units = [32, 128]
```

```
embedding_layer_type = 'glove'
bidirectional = False
rnn_drop_rate = 0
drop_rate = 0


for rnn_layer_unit in rnn_layer_units:
    num_param, val_loss, val_acc, train_time, infer_time = train_model(
        x_train,
        y_train,
        x_val,
        y_val,
        rnn_type=best_rnn_type,
        num_rnn_layers=num_rnn_layers,
        rnn_layer_unit=rnn_layer_unit,
        embedding_layer_type=embedding_layer_type,
        bidirectional=bidirectional,
        rnn_drop_rate=rnn_drop_rate,
        drop_rate=drop_rate
    )

    print(f"{num_rnn_layers} layers;{best_rnn_type};{rnn_layer_unit} units;
 ↪{embedding_layer_type} embed;bidirec {bidirectional};drop {drop_rate};
 ↪rnn_drop {rnn_drop_rate} => {num_param} Params;val_loss={val_loss};
 ↪val_acc={round(val_acc,2)};train_time={round(train_time,2)}s;
 ↪infer_time={round(infer_time,2)}s")

    result_df.loc[len(result_df.index)] = [
        best_rnn_type,
        num_rnn_layers,
        rnn_layer_unit,
        embedding_layer_type,
        bidirectional,
        rnn_drop_rate,
        drop_rate,
        num_param,
        val_loss,
        val_acc,
        train_time,
        infer_time
    ]

plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend()
plt.title(f'Training Loss vs epoch')
plt.show()
```

```
1 layers;gru;32 units;glove embed;bidirec False;drop 0;rnn_drop 0 => 16366 Param
s;val_loss=0.3148992359638214;val_acc=0.86;train_time=189.24s;infer_time=0.37s
1 layers;gru;128 units;glove embed;bidirec False;drop 0;rnn_drop 0 => 101422 Par
ams;val_loss=0.29255348443984985;val_acc=0.88;train_time=225.28s;infer_time=0.61
s
```



[ ]:
```
result_df
```

[ ]:

	RNN Type	RNN Layer	RNN Size	Embedding Layer	Bidirectional	\
0	lstm	1	64	glove	False	
1	gru	1	64	glove	False	
2	gru	1	32	glove	False	
3	gru	1	128	glove	False	

	RNN Dropout Rate	Dropout Rate	Num Params	Val Loss	Val Accuracy	\
0	0	0	48942	0.569545	0.7310	
1	0	0	38574	0.283425	0.8775	
2	0	0	16366	0.314899	0.8640	
3	0	0	101422	0.292553	0.8850	

	Train Time (s)	Infer Time (s)
0	240.921910	0.466113
1	185.895412	0.512385
2	189.243573	0.374345
3	225.282186	0.609460

[ ]:
```
best_rnn_layer_unit = result_df.sort_values(
    by=['Val Accuracy', 'Val Loss'],
    ascending=[False, True]
)['RNN Size'].iloc[0]
```

```
best_rnn_layer_unit
```

[ ]: 128

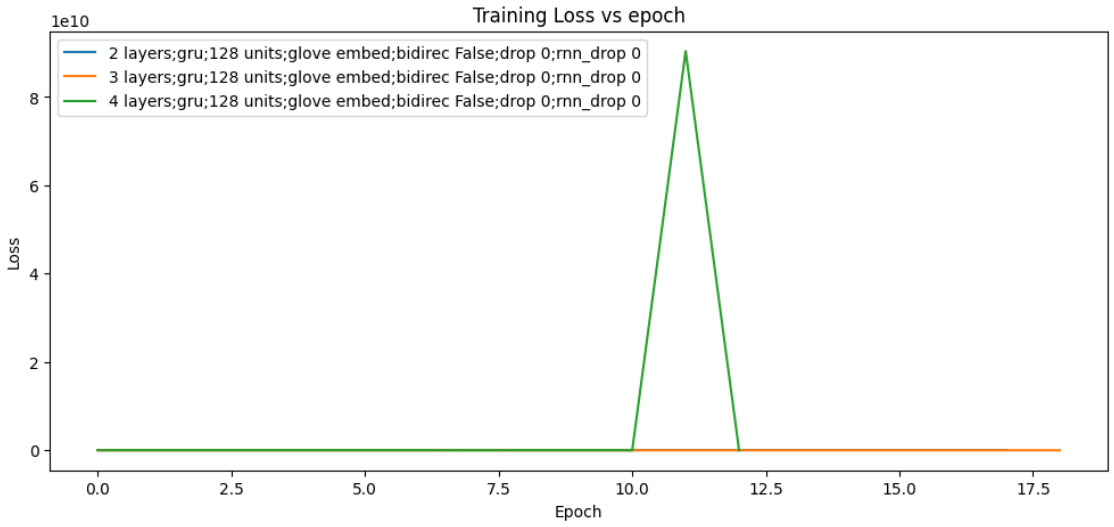
1.5 Task 5

For the best model above vary the number of stack layers of RNN : [2, 3, 4]. One is done previously

[ ]:
```
num_rnn_layers = [2, 3, 4]
embedding_layer_type = 'glove'
bidirectional = False
rnn_drop_rate = 0
drop_rate = 0

for num_rnn_layer in num_rnn_layers:
    num_param, val_loss, val_acc, train_time, infer_time = train_model(
        x_train,
        y_train,
        x_val,
        y_val,
        rnn_type=best_rnn_type,
        num_rnn_layers=num_rnn_layer,
        rnn_layer_unit=best_rnn_layer_unit,
        embedding_layer_type=embedding_layer_type,
        bidirectional=bidirectional,
        rnn_drop_rate=rnn_drop_rate,
        drop_rate=drop_rate
    )

    print(f"{num_rnn_layer} layers;{best_rnn_type};{best_rnn_layer_unit} units;
 ↪{embedding_layer_type} embed;bidirec {bidirectional};drop {drop_rate};
 ↪rnn_drop {rnn_drop_rate} => {num_param} Params;val_loss={val_loss};
 ↪val_acc={round(val_acc,2)};train_time={round(train_time,2)}s;
 ↪infer_time={round(infer_time,2)}s")

    result_df.loc[len(result_df.index)] = [
        best_rnn_type,
        num_rnn_layer,
        best_rnn_layer_unit,
        embedding_layer_type,
        bidirectional,
        rnn_drop_rate,
        drop_rate,
        num_param,
        val_loss,
        val_acc,
```

```
        train_time,
        infer_time
    ]

plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend()
plt.title(f'Training Loss vs epoch')
plt.show()
```

```
2 layers;gru;128 units;glove embed;bidirec False;drop 0;rnn_drop 0 => 200494 Par
ams;val_loss=0.3106384575366974;val_acc=0.86;train_time=472.7s;infer_time=1.34s
3 layers;gru;128 units;glove embed;bidirec False;drop 0;rnn_drop 0 => 299566 Par
ams;val_loss=0.2740836441516876;val_acc=0.89;train_time=740.85s;infer_time=1.57s
4 layers;gru;128 units;glove embed;bidirec False;drop 0;rnn_drop 0 => 398638 Par
ams;val_loss=0.2967704236507416;val_acc=0.88;train_time=777.69s;infer_time=1.98s
```



[ ]:
```
result_df
```

[ ]:

	RNN Type	RNN Layer	RNN Size	Embedding Layer	Bidirectional	\
0	lstm	1	64	glove	False	
1	gru	1	64	glove	False	
2	gru	1	32	glove	False	
3	gru	1	128	glove	False	
4	gru	2	128	glove	False	
5	gru	3	128	glove	False	
6	gru	4	128	glove	False	

	RNN Dropout Rate	Dropout Rate	Num Params	Val Loss	Val Accuracy	\

```
0                0              0       48942  0.569545        0.7310
1                0              0       38574  0.283425        0.8775
2                0              0       16366  0.314899        0.8640
3                0              0      101422  0.292553        0.8850
4                0              0      200494  0.310638        0.8550
5                0              0      299566  0.274084        0.8930
6                0              0      398638  0.296770        0.8835

   Train Time (s)  Infer Time (s)
0      240.921910        0.466113
1      185.895412        0.512385
2      189.243573        0.374345
3      225.282186        0.609460
4      472.700390        1.343001
5      740.848774        1.574941
6      777.693047        1.979421
```

[ ]:
```
best_num_rnn_layer = result_df.sort_values(
    by=['Val Accuracy', 'Val Loss'],
    ascending=[False, True]
)['RNN Layer'].iloc[0]

best_num_rnn_layer
```

[ ]:
```
3
```

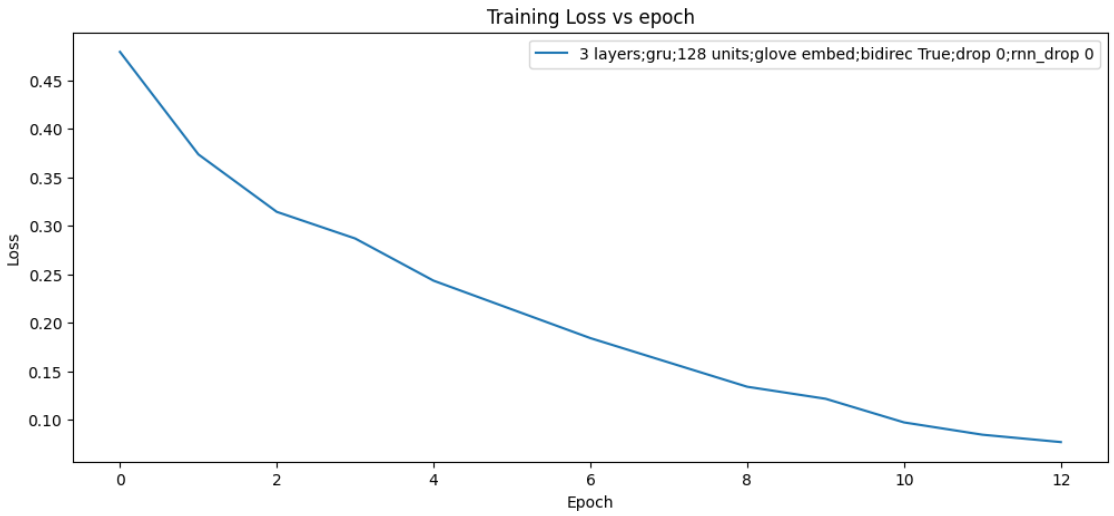
1.6 Task 6

For the best model above run a bidirectional RNN model: UniDirectional is done previously.

[ ]:
```
embedding_layer_type = 'glove'
bidirectional = True
rnn_drop_rate = 0
drop_rate = 0

num_param, val_loss, val_acc, train_time, infer_time = train_model(
    x_train,
    y_train,
    x_val,
    y_val,
    rnn_type=best_rnn_type,
    num_rnn_layers=best_num_rnn_layer,
    rnn_layer_unit=best_rnn_layer_unit,
    embedding_layer_type=embedding_layer_type,
    bidirectional=bidirectional,
    rnn_drop_rate=rnn_drop_rate,
    drop_rate=drop_rate
```

```
)

print(f"{best_num_rnn_layer} layers;{best_rnn_type};{best_rnn_layer_unit} units;
  ↪{embedding_layer_type} embed;bidirec {bidirectional};drop {drop_rate};
  ↪rnn_drop {rnn_drop_rate} => {num_param} Params;val_loss={val_loss};
  ↪val_acc={round(val_acc,2)};train_time={round(train_time,2)}s;
  ↪infer_time={round(infer_time,2)}s")

result_df.loc[len(result_df.index)] = [
    best_rnn_type,
    best_num_rnn_layer,
    best_rnn_layer_unit,
    embedding_layer_type,
    bidirectional,
    rnn_drop_rate,
    drop_rate,
    num_param,
    val_loss,
    val_acc,
    train_time,
    infer_time
]

plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend()
plt.title(f'Training Loss vs epoch')
plt.show()
```

```
3 layers;gru;128 units;glove embed;bidirec True;drop 0;rnn_drop 0 => 795438 Para
ms;val_loss=0.29917457699775696;val_acc=0.88;train_time=694.56s;infer_time=2.07s
```



[ ]:
```
result_df
```

[ ]:

	RNN Type	RNN Layer	RNN Size	Embedding Layer	Bidirectional	RNN Dropout Rate	Dropout Rate	Num Params	Val Loss	Val Accuracy	Train Time (s)	Infer Time (s)
0	lstm	1	64	glove	False	0	0	48942	0.569545	0.7310	240.921910	0.466113
1	gru	1	64	glove	False	0	0	38574	0.283425	0.8775	185.895412	0.512385
2	gru	1	32	glove	False	0	0	16366	0.314899	0.8640	189.243573	0.374345
3	gru	1	128	glove	False	0	0	101422	0.292553	0.8850	225.282186	0.609460
4	gru	2	128	glove	False	0	0	200494	0.310638	0.8550	472.700390	1.343001
5	gru	3	128	glove	False	0	0	299566	0.274084	0.8930	740.848774	1.574941
6	gru	4	128	glove	False	0	0	398638	0.296770	0.8835	777.693047	1.979421
7	gru	3	128	glove	True	0	0	795438	0.299175	0.8830	694.564792	2.074273

[ ]:
```
best_bidirectional = result_df.sort_values(
    by=['Val Accuracy', 'Val Loss'],
    ascending=[False, True]
)['Bidirectional'].iloc[0]

best_bidirectional
```

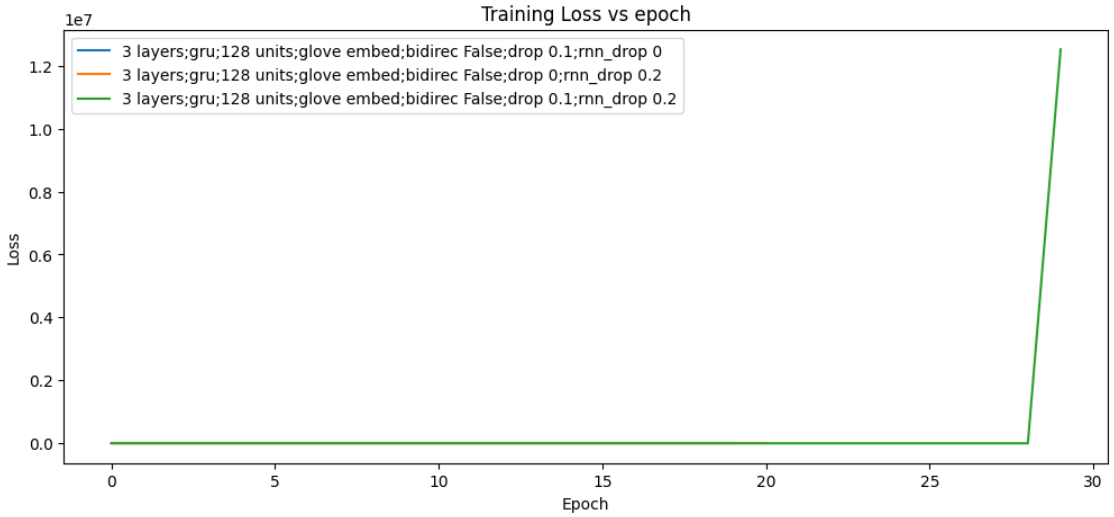
[ ]:
```
False
```

1.7 Task 7

For the best model above try Dropout: 0.1, Recurrent Dropout:0.2, and both together.

[ ]:
```
embedding_layer_type = 'glove'
rnn_drop_rates = [0, 0.2, 0.2]
drop_rates = [0.1, 0, 0.1]

for rnn_drop_rate, drop_rate in zip(rnn_drop_rates, drop_rates):
    num_param, val_loss, val_acc, train_time, infer_time = train_model(
        x_train,
        y_train,
        x_val,
        y_val,
        rnn_type=best_rnn_type,
        num_rnn_layers=best_num_rnn_layer,
        rnn_layer_unit=best_rnn_layer_unit,
        embedding_layer_type=embedding_layer_type,
        bidirectional=best_bidirectional,
        rnn_drop_rate=rnn_drop_rate,
        drop_rate=drop_rate
    )

    print(f"{best_num_rnn_layer} layers;{best_rnn_type};{best_rnn_layer_unit}␣
 ↪units;{embedding_layer_type} embed;bidirec {best_bidirectional};drop␣
 ↪{drop_rate};rnn_drop {rnn_drop_rate} => {num_param} Params;
 ↪val_loss={val_loss};val_acc={round(val_acc,2)};
 ↪train_time={round(train_time,2)}s;infer_time={round(infer_time,2)}s")

    result_df.loc[len(result_df.index)] = [
        best_rnn_type,
        best_num_rnn_layer,
        best_rnn_layer_unit,
        embedding_layer_type,
        best_bidirectional,
        rnn_drop_rate,
        drop_rate,
        num_param,
        val_loss,
        val_acc,
        train_time,
        infer_time
    ]

plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend()
plt.title(f'Training Loss vs epoch')
plt.show()
```

```
3 layers;gru;128 units;glove embed;bidirec False;drop 0.1;rnn_drop 0 => 299566 P
arams;val_loss=0.2802678644657135;val_acc=0.88;train_time=696.63s;infer_time=1.6
7s
3 layers;gru;128 units;glove embed;bidirec False;drop 0;rnn_drop 0.2 => 299566 P
arams;val_loss=0.24916750192642212;val_acc=0.89;train_time=757.42s;infer_time=1.
52s
3 layers;gru;128 units;glove embed;bidirec False;drop 0.1;rnn_drop 0.2 => 299566
Params;val_loss=0.24427096545696259;val_acc=0.9;train_time=1084.17s;infer_time=1
.71s
```



[ ]:
```
result_df
```

[ ]:

	RNN Type	RNN Layer	RNN Size	Embedding Layer	Bidirectional	RNN Dropout Rate	Dropout Rate	Num Params	Val Loss	Val Accuracy
0	lstm	1	64	glove	False	0.0	0.0	48942	0.569545	0.7310
1	gru	1	64	glove	False	0.0	0.0	38574	0.283425	0.8775
2	gru	1	32	glove	False	0.0	0.0	16366	0.314899	0.8640
3	gru	1	128	glove	False	0.0	0.0	101422	0.292553	0.8850
4	gru	2	128	glove	False					
5	gru	3	128	glove	False					
6	gru	4	128	glove	False					
7	gru	3	128	glove	True					
8	gru	3	128	glove	False					
9	gru	3	128	glove	False					
10	gru	3	128	glove	False					

```
4                0.0           0.0      200494  0.310638        0.8550
5                0.0           0.0      299566  0.274084        0.8930
6                0.0           0.0      398638  0.296770        0.8835
7                0.0           0.0      795438  0.299175        0.8830
8                0.0           0.1      299566  0.280268        0.8845
9                0.2           0.0      299566  0.249168        0.8925
10               0.2           0.1      299566  0.244271        0.9040

    Train Time (s)  Infer Time (s)
0        240.921910        0.466113
1        185.895412        0.512385
2        189.243573        0.374345
3        225.282186        0.609460
4        472.700390        1.343001
5        740.848774        1.574941
6        777.693047        1.979421
7        694.564792        2.074273
8        696.628811        1.670645
9        757.417940        1.516263
10      1084.169545        1.713555
```

[ ]:
```
best_rnn_drop_rate = result_df.sort_values(
    by=['Val Accuracy', 'Val Loss'],
    ascending=[False, True]
)['RNN Dropout Rate'].iloc[0]

best_rnn_drop_rate
```

[ ]:
```
0.2
```

[ ]:
```
best_drop_rate = result_df.sort_values(
    by=['Val Accuracy', 'Val Loss'],
    ascending=[False, True]
)['Dropout Rate'].iloc[0]

best_drop_rate
```

[ ]:
```
0.1
```

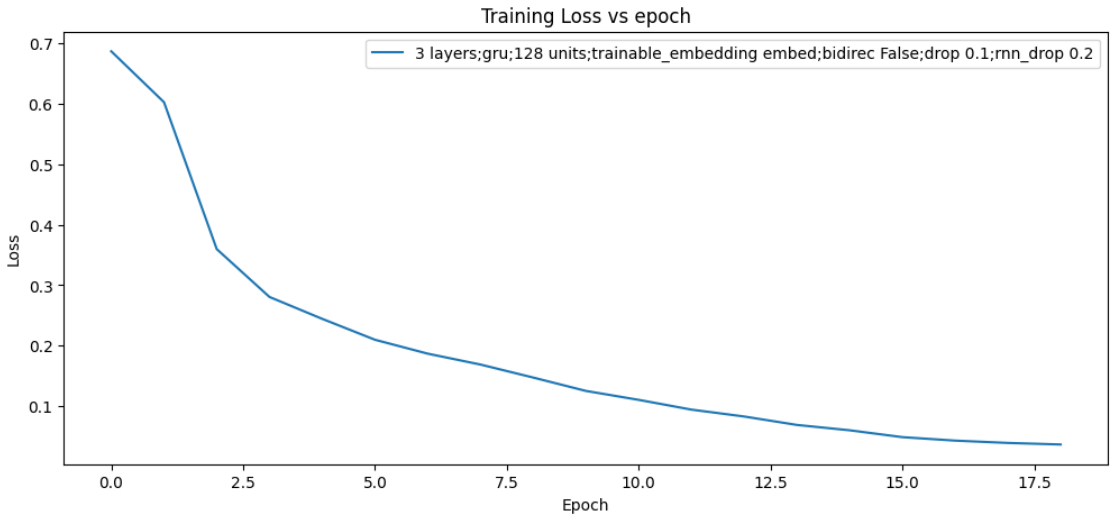
1.8 Task 8/9

For the best model above consider training a self trainable embedding layer, and one hot encoding layer. Discuss the major differences in performance.

[ ]:
```
# one_hot skipped because of RAM limitation
# unable to create 40k x 40k matrix
embedding_layer_types = ['trainable_embedding']
```

```
for embedding_layer_type in embedding_layer_types:
    num_param, val_loss, val_acc, train_time, infer_time = train_model(
        x_train,
        y_train,
        x_val,
        y_val,
        rnn_type=best_rnn_type,
        num_rnn_layers=best_num_rnn_layer,
        rnn_layer_unit=best_rnn_layer_unit,
        embedding_layer_type=embedding_layer_type,
        bidirectional=best_bidirectional,
        rnn_drop_rate=best_rnn_drop_rate,
        drop_rate=best_drop_rate
    )

    print(f"{best_num_rnn_layer} layers;{best_rnn_type};{best_rnn_layer_unit}␣
 ↪units;{embedding_layer_type} embed;bidirec {best_bidirectional};drop␣
 ↪{best_drop_rate};rnn_drop {best_rnn_drop_rate} => {num_param} Params;
 ↪val_loss={val_loss};val_acc={round(val_acc,2)};
 ↪train_time={round(train_time,2)}s;infer_time={round(infer_time,2)}s")

    result_df.loc[len(result_df.index)] = [
        best_rnn_type,
        best_num_rnn_layer,
        best_rnn_layer_unit,
        embedding_layer_type,
        best_bidirectional,
        best_rnn_drop_rate,
        best_drop_rate,
        num_param,
        val_loss,
        val_acc,
        train_time,
        infer_time
    ]

plt.ylabel('Loss')
plt.xlabel('Epoch')
plt.legend()
plt.title(f'Training Loss vs epoch')
plt.show()
```

```
3 layers;gru;128 units;trainable_embedding embed;bidirec False;drop 0.1;rnn_drop
0.2 => 3150566 Params;val_loss=0.2810792624950409;val_acc=0.89;train_time=708.96
s;infer_time=1.58s
```



[ ]:
```
result_df
```

[ ]:

	RNN Type	RNN Layer	RNN Size	Embedding Layer	Bidirectional	RNN Dropout Rate	Dropout Rate	Num Params	Val Loss	Val Accuracy
0	lstm	1	64	glove	False	0.0	0.0	48942	0.569545	0.7310
1	gru	1	64	glove	False	0.0	0.0	38574	0.283425	0.8775
2	gru	1	32	glove	False	0.0	0.0	16366	0.314899	0.8640
3	gru	1	128	glove	False	0.0	0.0	101422	0.292553	0.8850
4	gru	2	128	glove	False	0.0	0.0	200494	0.310638	0.8550
5	gru	3	128	glove	False	0.0	0.0	299566	0.274084	0.8930
6	gru	4	128	glove	False	0.0	0.0	398638	0.296770	0.8835
7	gru	3	128	glove	True	0.0	0.0	795438	0.299175	0.8830
8	gru	3	128	glove	False	0.0	0.1	299566	0.280268	0.8845
9	gru	3	128	glove	False	0.2	0.0	299566	0.249168	0.8925
10	gru	3	128	glove	False	0.2	0.1	299566	0.244271	0.9040
11	gru	3	128	trainable_embedding	False	0.2	0.1	3150566	0.281079	0.8880

```
    Train Time (s)  Infer Time (s)
0        240.921910        0.466113
1        185.895412        0.512385
2        189.243573        0.374345
3        225.282186        0.609460
4        472.700390        1.343001
5        740.848774        1.574941
6        777.693047        1.979421
7        694.564792        2.074273
8        696.628811        1.670645
9        757.417940        1.516263
10      1084.169545        1.713555
11       708.963408        1.581350
```

[ ]:
```
best_embedding_layer_type = result_df.sort_values(
    by=['Val Accuracy', 'Val Loss'],
    ascending=[False, True]
)['Embedding Layer'].iloc[0]

best_embedding_layer_type
```

[ ]:
```
'glove'
```

1.9 Task 10

Compare the number of parameters, training and inference computation time, Training Loss graph, accuracy.

[ ]:
```
result_df
```

[ ]:
```
    RNN Type  RNN Layer  RNN Size      Embedding Layer  Bidirectional  \
0       lstm          1        64                glove          False
1        gru          1        64                glove          False
2        gru          1        32                glove          False
3        gru          1       128                glove          False
4        gru          2       128                glove          False
5        gru          3       128                glove          False
6        gru          4       128                glove          False
7        gru          3       128                glove           True
8        gru          3       128                glove          False
9        gru          3       128                glove          False
10       gru          3       128                glove          False
11       gru          3       128  trainable_embedding          False

    RNN Dropout Rate  Dropout Rate  Num Params  Val Loss  Val Accuracy  \
0                0.0           0.0       48942  0.569545        0.7310
```

1	0.0	0.0	38574	0.283425	0.8775
2	0.0	0.0	16366	0.314899	0.8640
3	0.0	0.0	101422	0.292553	0.8850
4	0.0	0.0	200494	0.310638	0.8550
5	0.0	0.0	299566	0.274084	0.8930
6	0.0	0.0	398638	0.296770	0.8835
7	0.0	0.0	795438	0.299175	0.8830
8	0.0	0.1	299566	0.280268	0.8845
9	0.2	0.0	299566	0.249168	0.8925
10	0.2	0.1	299566	0.244271	0.9040
11	0.2	0.1	3150566	0.281079	0.8880

	Train Time (s)	Infer Time (s)
0	240.921910	0.466113
1	185.895412	0.512385
2	189.243573	0.374345
3	225.282186	0.609460
4	472.700390	1.343001
5	740.848774	1.574941
6	777.693047	1.979421
7	694.564792	2.074273
8	696.628811	1.670645
9	757.417940	1.516263
10	1084.169545	1.713555
11	708.963408	1.581350

1.10 Task 11

Write a review of your own and test your model. Save the model checkpoint for later use. [Note: To verify the best model is saved, re-run the notebook and only perform testing]

[ ]:
```
print(f"best_rnn_type = {best_rnn_type}")
print(f"best_num_rnn_layer = {best_num_rnn_layer}")
print(f"best_rnn_layer_unit = {best_rnn_layer_unit}")
print(f"best_embedding_layer_type = {best_embedding_layer_type}")
print(f"best_bidirectional = {best_bidirectional}")
print(f"best_rnn_drop_rate = {best_rnn_drop_rate}")
print(f"best_drop_rate = {best_drop_rate}")
```

```
best_rnn_type = gru
best_num_rnn_layer = 3
best_rnn_layer_unit = 128
best_embedding_layer_type = glove
best_bidirectional = False
best_rnn_drop_rate = 0.2
best_drop_rate = 0.1
```

[ ]:
```
model = train_model(
        x_train,
        y_train,
        x_val,
        y_val,
        rnn_type=best_rnn_type,
        num_rnn_layers=best_num_rnn_layer,
        rnn_layer_unit=best_rnn_layer_unit,
        embedding_layer_type=best_embedding_layer_type,
        bidirectional=best_bidirectional,
        rnn_drop_rate=best_rnn_drop_rate,
        drop_rate=best_drop_rate,
        give_model=True
    )
```

[ ]:
```
val_loss, val_acc = model.evaluate(x_test, y_test)

print(f"val_loss = {val_loss}")
print(f"val_acc  = {val_acc }")
```

```
63/63 [==============================] - 2s 27ms/step - loss: 0.2473 - accuracy:
0.9000
val_loss = 0.24732160568237305
val_acc  = 0.8999999761581421
```

[ ]:
```
model.save('best_model')
```

```
INFO:tensorflow:Assets written to: best_model/assets

WARNING:absl:<keras.layers.recurrent.GRUCell object at 0x7f87c2c56ca0> has the
same name 'GRUCell' as a built-in Keras object. Consider renaming <class
'keras.layers.recurrent.GRUCell'> to avoid naming conflicts when loading with
`tf.keras.models.load_model`. If renaming is not possible, pass the object in
the `custom_objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.GRUCell object at 0x7f87c1f40a60> has the
same name 'GRUCell' as a built-in Keras object. Consider renaming <class
'keras.layers.recurrent.GRUCell'> to avoid naming conflicts when loading with
`tf.keras.models.load_model`. If renaming is not possible, pass the object in
the `custom_objects` parameter of the load function.
WARNING:absl:<keras.layers.recurrent.GRUCell object at 0x7f87c39318b0> has the
same name 'GRUCell' as a built-in Keras object. Consider renaming <class
'keras.layers.recurrent.GRUCell'> to avoid naming conflicts when loading with
`tf.keras.models.load_model`. If renaming is not possible, pass the object in
the `custom_objects` parameter of the load function.
```

[ ]:
```
from tensorflow.keras.models import load_model

model = load_model('best_model')
```

```
val_loss, val_acc = model.evaluate(x_test, y_test)

print(f"val_loss = {val_loss}")
print(f"val_acc  = {val_acc }")
```

```
63/63 [==============================] - 2s 34ms/step - loss: 0.2473 - accuracy:
0.9000
val_loss = 0.24732160568237305
val_acc  = 0.8999999761581421
```

1.11 Task 12

For the best model try the Hindi movie review dataset https://www.kaggle.com/disisbig/hindi-movie-reviews-dataset (use self trainable embedding layer or any other Hindi Word2Vec representation).

[ ]:
```
HINDI_REVIEW_TRAIN_PATH = "./../ML_DRIVE/Assign_7/Hindi Movie/train.csv"
HINDI_REVIEW_VAL_PATH = "./../ML_DRIVE/Assign_7/Hindi Movie/valid.csv"
```

[ ]:
```
import pandas as pd

hindi_train_df = pd.read_csv(HINDI_REVIEW_TRAIN_PATH)
hindi_val_df = pd.read_csv(HINDI_REVIEW_VAL_PATH)

hindi_train_df
```

[ ]:
```
                                                  text  experience
0                -                 …             2
1                                    …              0
2                -                   …             2
3          :\n               . .,     …              0
4      1959                            …              1
..                                                      …          …
713    31      1984                        …              1
714    \n\n                            …              1
715    Chandermohan.sharma@timesgroup.com          …              2
716         :\n          ,        ,     …              2
717       2                            …             2

[718 rows x 2 columns]
```

[ ]:
```
hindi_train_df['experience'] = np.where(
    hindi_train_df['experience'] >= 1, 1, 0
)

hindi_val_df['experience'] = np.where(
    hindi_val_df['experience'] >= 1, 1, 0
)
```

[ ]:
```
from tensorflow.keras.layers import TextVectorization

vectorizer = TextVectorization(output_sequence_length=100)
vectorizer.adapt(hindi_train_df['text'].to_list())
vectorizer.get_vocabulary()[:5]
```

[ ]:
```
['', '[UNK]', ' ', ' ', ' ']
```

[ ]:
```
voc = vectorizer.get_vocabulary()
word_index = dict(zip(voc, range(len(voc))))
num_tokens = len(voc) + 2  # +2 for "empty" and "unknown"
embedding_dim = 100  # cause using glove 100 model
```

[ ]:
```
hindi_x_train =  vectorizer(
    np.array(
        [[s] for s in hindi_train_df['text'].tolist()]
    )
).numpy()

hindi_x_val =  vectorizer(
    np.array(
        [[s] for s in hindi_val_df['text'].tolist()]
    )
).numpy()
```

[ ]:
```
from tensorflow.keras.utils import to_categorical

hindi_y_train = to_categorical(hindi_train_df['experience'].tolist())
hindi_y_val = to_categorical(hindi_val_df['experience'].tolist())
```

[ ]:
```
from tensorflow.keras.models import Sequential
from tensorflow.keras.layers import Input

hindi_model = Sequential()
hindi_model.add(Input(shape=(None, ), dtype="int64"))
hindi_model.add(Embedding(num_tokens, embedding_dim))

for layer in model.layers[1:]:
    hindi_model.add(layer)
    hindi_model.layers[-1].trainable = False

hindi_model.summary()
```

```
Model: "sequential_4"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
```

```
 embedding_4 (Embedding)     (None, None, 100)         2281600

 dropout_12 (Dropout)        (None, None, 100)         0

 gru_27 (GRU)                (None, None, 128)         88320

 dropout_13 (Dropout)        (None, None, 128)         0

 gru_28 (GRU)                (None, None, 128)         99072

 dropout_14 (Dropout)        (None, None, 128)         0

 gru_29 (GRU)                (None, 128)               99072

 dropout_15 (Dropout)        (None, 128)               0

 dense_24 (Dense)            (None, 100)               12900

 dense_25 (Dense)            (None, 2)                 202

=================================================================
Total params: 2,581,166
Trainable params: 2,281,600
Non-trainable params: 299,566
_________________________________________________________________
```

[ ]:
```python
from tensorflow.keras.callbacks import EarlyStopping

model.compile(
    loss="categorical_crossentropy", metrics=["accuracy"]
)

callback = [
    EarlyStopping(
        monitor='val_loss',
        patience=10,
        restore_best_weights=True
    )
]

history = model.fit(
    hindi_x_train,
    hindi_y_train,
    epochs=100,
    validation_data=(hindi_x_val, hindi_y_val),
    callbacks=callback,
    verbose=2
```

```
)
```

```
Epoch 1/100
23/23 - 6s - loss: 0.9936 - accuracy: 0.5056 - val_loss: 0.2473 - val_accuracy:
0.9000 - 6s/epoch - 243ms/step
Epoch 2/100
23/23 - 3s - loss: 0.9819 - accuracy: 0.5223 - val_loss: 0.2473 - val_accuracy:
0.9000 - 3s/epoch - 142ms/step
Epoch 3/100
23/23 - 3s - loss: 0.9803 - accuracy: 0.5028 - val_loss: 0.2473 - val_accuracy:
0.9000 - 3s/epoch - 141ms/step
Epoch 4/100
23/23 - 3s - loss: 0.9939 - accuracy: 0.5265 - val_loss: 0.2473 - val_accuracy:
0.9000 - 3s/epoch - 141ms/step
Epoch 5/100
23/23 - 4s - loss: 1.0033 - accuracy: 0.5125 - val_loss: 0.2473 - val_accuracy:
0.9000 - 4s/epoch - 154ms/step
Epoch 6/100
23/23 - 4s - loss: 0.9552 - accuracy: 0.5320 - val_loss: 0.2473 - val_accuracy:
0.9000 - 4s/epoch - 171ms/step
Epoch 7/100
23/23 - 4s - loss: 0.9923 - accuracy: 0.5237 - val_loss: 0.2473 - val_accuracy:
0.9000 - 4s/epoch - 154ms/step
Epoch 8/100
23/23 - 4s - loss: 0.9578 - accuracy: 0.5362 - val_loss: 0.2473 - val_accuracy:
0.9000 - 4s/epoch - 161ms/step
Epoch 9/100
23/23 - 4s - loss: 0.9693 - accuracy: 0.5209 - val_loss: 0.2473 - val_accuracy:
0.9000 - 4s/epoch - 170ms/step
Epoch 10/100
23/23 - 4s - loss: 0.9671 - accuracy: 0.5209 - val_loss: 0.2473 - val_accuracy:
0.9000 - 4s/epoch - 153ms/step
Epoch 11/100
23/23 - 3s - loss: 0.9788 - accuracy: 0.5348 - val_loss: 0.2473 - val_accuracy:
0.9000 - 3s/epoch - 145ms/step
```

1.12 Task 13

Discuss the time required and other practical challenges in training with the whole Amazon review dataset.

1. My Whole 16 GB RAM was near occupied with only 12000 observations, actual dataset have 568454 rows, hence we need abysmal amount of RAM to store its embedding (unique_words * 100) (100 cause of glove 100)
2. This notebook takes like 2 hours to fully run with only 12000 observations, actual dataset have 568454 rows, hence we need abysmal Training Time also
3. Model parameters did not allows GPU acceleration to work