# Assignment 7


- Name: Arnab Sen
- Enrolment Number: 510519006
- Dept: CST


## Task 1

In [ ]:

```
import tensorflow as tf
import os
import pandas as pd
import numpy as np
from tensorflow.keras.layers import TextVectorization
import tensorflow.keras as keras
from tensorflow.keras.layers import Embedding
from tensorflow.keras import Sequential
from tensorflow.keras.layers import Dense, Input, LSTM, GRU, Bidirectional, Drop
out
from tensorflow.keras.callbacks import EarlyStopping
import matplotlib.pyplot as plt
import time
from keras.utils.layer_utils import count_params
from tensorflow.keras.utils import to_categorical

from tensorflow.keras.models import load_model
```

In [ ]:

```
os.environ["TF_CPP_MIN_LOG_LEVEL"] = "3"
tf.config.set_visible_devices([], 'GPU')
```

In [ ]:

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

In [ ]:

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

Out[ ]:

| | Id | ProductId | UserId | ProfileName | HelpfulnessNumerator | HelpfulnessDeno |
|---|---|---|---|---|---|---|
| **0** | 1 | B001E4KFG0 | A3SGXH7AUHU8GW | delmartian | 1 | |
| **1** | 2 | B00813GRG4 | A1D87F6ZCVE5NK | dll pa | 0 | |
| **2** | 3 | B000LQOCH0 | ABXLMWJIXXAIN | Natalia Corres "Natalia Corres" | 1 | |
| **3** | 4 | B000UA0QIQ | A395BORC6FGVXV | Karl | 3 | |
| **4** | 5 | B006K2ZZ7K | A1UQRSCLF8GW1T | Michael D. Bigham "M. Wassir" | 0 | |

In [ ]:

```
review_df.columns
```

Out[ ]:

```
Index(['Id', 'ProductId', 'UserId', 'ProfileName', 'HelpfulnessNumer
ator',
       'HelpfulnessDenominator', 'Score', 'Time', 'Summary', 'Tex
t'],
      dtype='object')
```

In [ ]:

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

review_df = review_df[columns_to_keep]

review_df.iloc[0:1]
```

Out[ ]:

| | Score | Summary | Text |
|---|---|---|---|
| **0** | 5 | Good Quality Dog Food | I have bought several of the Vitality canned d... |

In [ ]:

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

review_df.iloc[0:1]
```

Out[ ]:

| | Score | full_review |
|---|---|---|
| **0** | 5 | Good Quality Dog Food I have bought several of... |

# Task 2

In [ ]:

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

Out[ ]:

| | 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 × 2 columns

In [ ]:

```
# 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())
```

In [ ]:

```
review_df
```

Out[ ]:

| | 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 × 2 columns

In [ ]:

```
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
```

Out[ ]:

| | 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 × 2 columns

In [ ]:

```
# using TextVectorization to index the vocabulary
vectorizer = TextVectorization(output_sequence_length=100)
vectorizer.adapt(train_df['full_review'].to_list())
```

In [ ]:

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

Out[ ]:

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

In [ ]:

```
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
```

In [ ]:

```
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.
```

In [ ]:

```
# now converting it into an embedding layer for using it directly on model

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 = 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.
        embedding_matrix[i] = embedding_vector
        hits += 1
    else:
        misses += 1

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

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

In [ ]:

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

In [ ]:

```
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()
```

In [ ]:

```
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())
```

In [ ]:

```
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.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;{embed
ding_layer_type} embed;bidirec {bidirectional};drop {drop_rate};rnn_drop {rnn_dr
op_rate}"
    )

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

In [ ]:

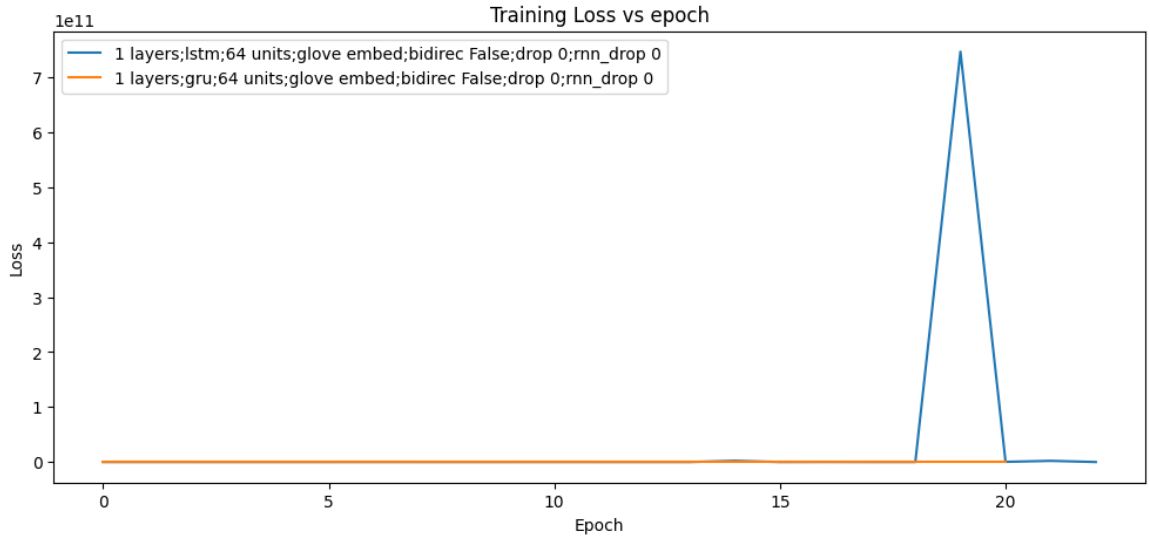
```
result_df = pd.DataFrame(columns=[
    'RNN Type',
    'RNN Layer',
    'RNN Size',
    'Embedding Layer',
    'Bidirectional',
    'RNN Dropout Rate',
    'Dropout Rate',
    'Num Params',
    'Val Loss',
    'Val Accuracy',
    'Train Time (s)',
    'Infer Time (s)'
])
```

# Task 3

In [ ]:

```
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_r
ate} => {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 Params;val_loss=0.5695447325706482;val_acc=0.73;train_time=2
40.92s;infer_time=0.47s
1 layers;gru;64 units;glove embed;bidirec False;drop 0;rnn_drop 0 =>
38574 Params;val_loss=0.28342491388320923;val_acc=0.88;train_time=18
5.9s;infer_time=0.51s
```




In [ ]:

```
result_df
```

Out[ ]:

| | RNN Type | RNN Layer | RNN Size | Embedding Layer | Bidirectional | RNN Dropout Rate | Dropout Rate | Num Params | Val Loss | Accura |
|---|---|---|---|---|---|---|---|---|---|---|
| **0** | lstm | 1 | 64 | glove | False | 0 | 0 | 48942 | 0.569545 | 0.73 |
| **1** | gru | 1 | 64 | glove | False | 0 | 0 | 38574 | 0.283425 | 0.87 |

In [ ]:

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

best_rnn_type
```

Out[ ]:

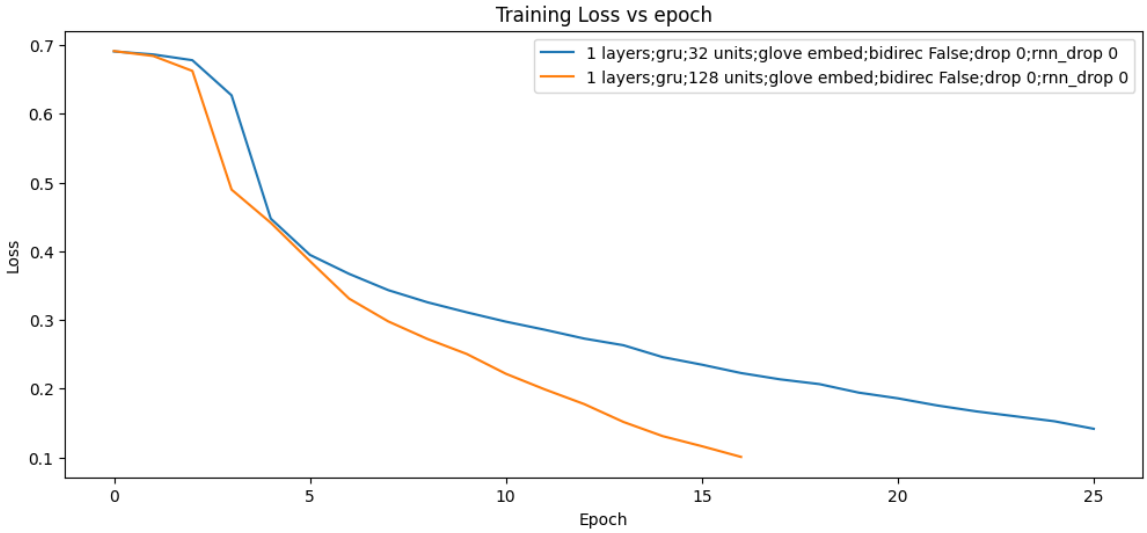
```
'gru'
```

# Task 4

In [ ]:

```
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;{embe
dding_layer_type} embed;bidirec {bidirectional};drop {drop_rate};rnn_drop {rnn_d
rop_rate} => {num_param} Params;val_loss={val_loss};val_acc={round(val_acc,2)};t
rain_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 Params;val_loss=0.3148992359638214;val_acc=0.86;train_time=18
9.24s;infer_time=0.37s
1 layers;gru;128 units;glove embed;bidirec False;drop 0;rnn_drop 0 =
> 101422 Params;val_loss=0.29255348443984985;val_acc=0.88;train_time
=225.28s;infer_time=0.61s
```




In [ ]:

```
result_df
```

Out[ ]:

| | RNN Type | RNN Layer | RNN Size | Embedding Layer | Bidirectional | RNN Dropout Rate | Dropout Rate | Num Params | Val Loss | V Accura |
|---|---|---|---|---|---|---|---|---|---|---|
| **0** | lstm | 1 | 64 | glove | False | 0 | 0 | 48942 | 0.569545 | 0.73 |
| **1** | gru | 1 | 64 | glove | False | 0 | 0 | 38574 | 0.283425 | 0.87 |
| **2** | gru | 1 | 32 | glove | False | 0 | 0 | 16366 | 0.314899 | 0.86 |
| **3** | gru | 1 | 128 | glove | False | 0 | 0 | 101422 | 0.292553 | 0.88 |

In [ ]:

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

best_rnn_layer_unit
```

Out[ ]:

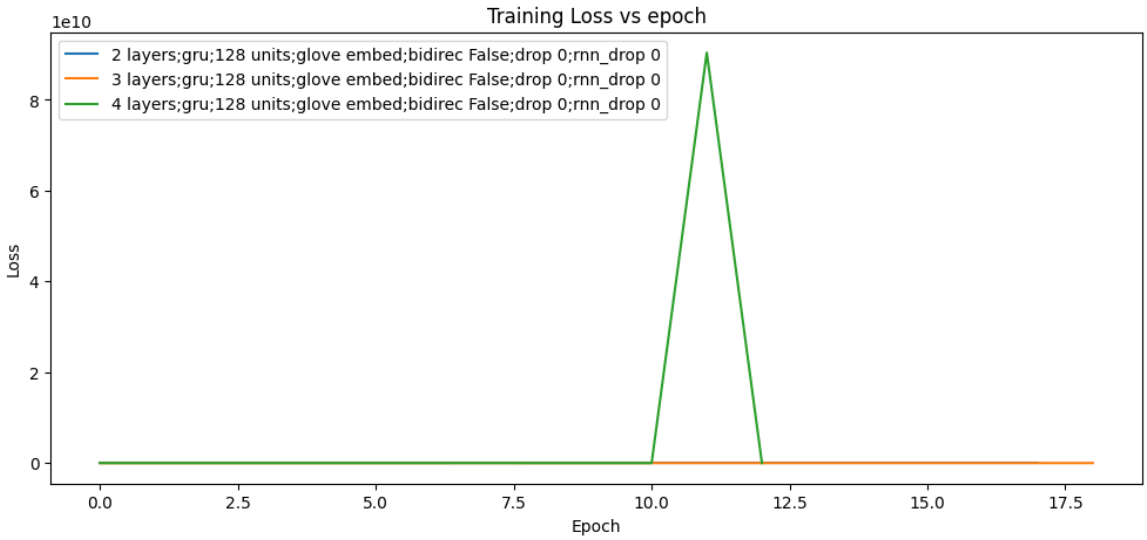
```
128
```

# Task 5

In [ ]:

```
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_ac
c,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 Params;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 Params;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 Params;val_loss=0.2967704236507416;val_acc=0.88;train_time=
777.69s;infer_time=1.98s
```




In [ ]:

```
result_df
```

Out[ ]:

| | RNN Type | RNN Layer | RNN Size | Embedding Layer | Bidirectional | RNN Dropout Rate | Dropout Rate | Num Params | Val Loss | V Accura |
|---|---|---|---|---|---|---|---|---|---|---|
| **0** | lstm | 1 | 64 | glove | False | 0 | 0 | 48942 | 0.569545 | 0.73 |
| **1** | gru | 1 | 64 | glove | False | 0 | 0 | 38574 | 0.283425 | 0.87 |
| **2** | gru | 1 | 32 | glove | False | 0 | 0 | 16366 | 0.314899 | 0.86 |
| **3** | gru | 1 | 128 | glove | False | 0 | 0 | 101422 | 0.292553 | 0.88 |
| **4** | gru | 2 | 128 | glove | False | 0 | 0 | 200494 | 0.310638 | 0.85 |
| **5** | gru | 3 | 128 | glove | False | 0 | 0 | 299566 | 0.274084 | 0.89 |
| **6** | gru | 4 | 128 | glove | False | 0 | 0 | 398638 | 0.296770 | 0.88 |

In [ ]:

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

best_num_rnn_layer
```

Out[ ]:

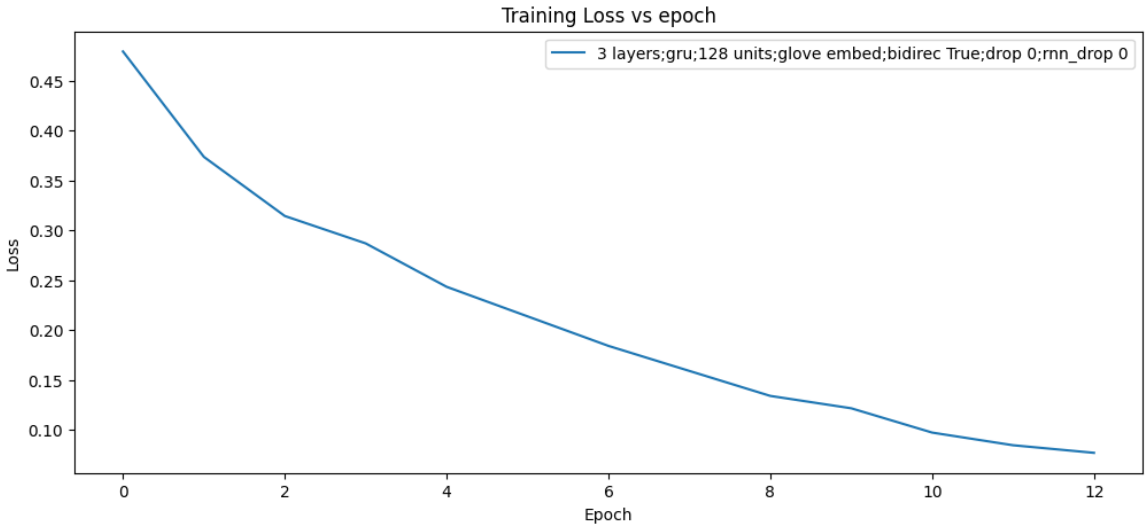
```
3
```

# Task 6

In [ ]:

```
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_ac
c,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 Params;val_loss=0.29917457699775696;val_acc=0.88;train_time=6
94.56s;infer_time=2.07s
```




In [ ]:

```
result_df
```

Out[ ]:

| | RNN Type | RNN Layer | RNN Size | Embedding Layer | Bidirectional | RNN Dropout Rate | Dropout Rate | Num Params | Val Loss | V Accura |
|---|---|---|---|---|---|---|---|---|---|---|
| **0** | lstm | 1 | 64 | glove | False | 0 | 0 | 48942 | 0.569545 | 0.73 |
| **1** | gru | 1 | 64 | glove | False | 0 | 0 | 38574 | 0.283425 | 0.87 |
| **2** | gru | 1 | 32 | glove | False | 0 | 0 | 16366 | 0.314899 | 0.86 |
| **3** | gru | 1 | 128 | glove | False | 0 | 0 | 101422 | 0.292553 | 0.88 |
| **4** | gru | 2 | 128 | glove | False | 0 | 0 | 200494 | 0.310638 | 0.85 |
| **5** | gru | 3 | 128 | glove | False | 0 | 0 | 299566 | 0.274084 | 0.89 |
| **6** | gru | 4 | 128 | glove | False | 0 | 0 | 398638 | 0.296770 | 0.88 |
| **7** | gru | 3 | 128 | glove | True | 0 | 0 | 795438 | 0.299175 | 0.88 |

In [ ]:

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

best_bidirectional
```

Out[ ]:

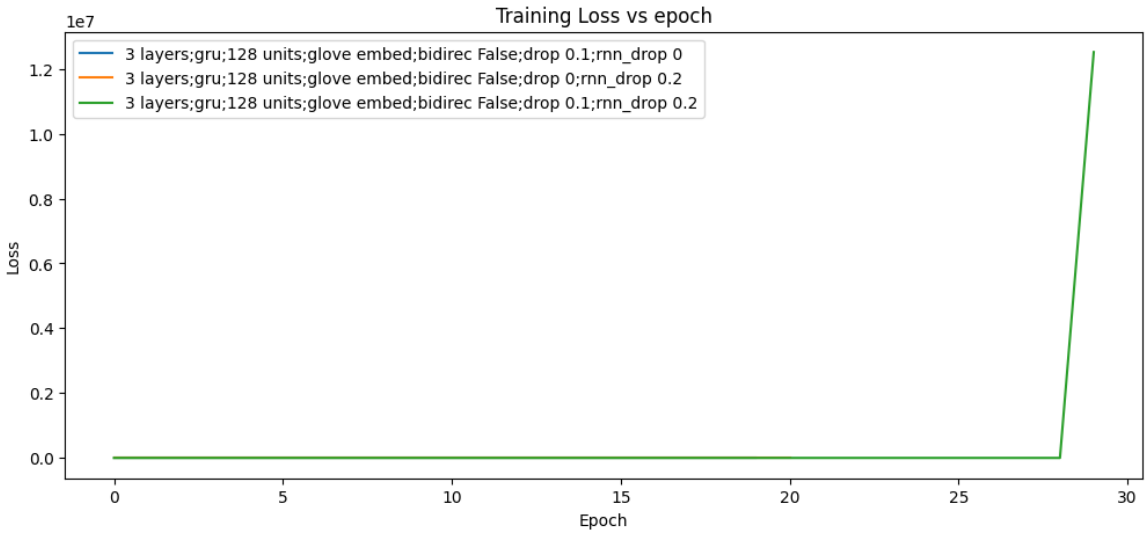
```
False
```

# Task 7

In [ ]:

```
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} un
its;{embedding_layer_type} embed;bidirec {best_bidirectional};drop {drop_rate};r
nn_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 Params;val_loss=0.2802678644657135;val_acc=0.88;train_time
=696.63s;infer_time=1.67s
3 layers;gru;128 units;glove embed;bidirec False;drop 0;rnn_drop 0.2
=> 299566 Params;val_loss=0.24916750192642212;val_acc=0.89;train_tim
e=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
```




In [ ]:

```
result_df
```

Out[ ]:

| | RNN Type | RNN Layer | RNN Size | Embedding Layer | Bidirectional | RNN Dropout Rate | Dropout Rate | Num Params | Val Loss | Accur |
|---|---|---|---|---|---|---|---|---|---|---|
| **0** | lstm | 1 | 64 | glove | False | 0.0 | 0.0 | 48942 | 0.569545 | 0.7 |
| **1** | gru | 1 | 64 | glove | False | 0.0 | 0.0 | 38574 | 0.283425 | 0.8 |
| **2** | gru | 1 | 32 | glove | False | 0.0 | 0.0 | 16366 | 0.314899 | 0.8 |
| **3** | gru | 1 | 128 | glove | False | 0.0 | 0.0 | 101422 | 0.292553 | 0.8 |
| **4** | gru | 2 | 128 | glove | False | 0.0 | 0.0 | 200494 | 0.310638 | 0.8 |
| **5** | gru | 3 | 128 | glove | False | 0.0 | 0.0 | 299566 | 0.274084 | 0.8 |
| **6** | gru | 4 | 128 | glove | False | 0.0 | 0.0 | 398638 | 0.296770 | 0.8 |
| **7** | gru | 3 | 128 | glove | True | 0.0 | 0.0 | 795438 | 0.299175 | 0.8 |
| **8** | gru | 3 | 128 | glove | False | 0.0 | 0.1 | 299566 | 0.280268 | 0.8 |
| **9** | gru | 3 | 128 | glove | False | 0.2 | 0.0 | 299566 | 0.249168 | 0.8 |
| **10** | gru | 3 | 128 | glove | False | 0.2 | 0.1 | 299566 | 0.244271 | 0.9 |

In [ ]:

```
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
```

Out[ ]:

```
0.2
```

In [ ]:

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

best_drop_rate
```

Out[ ]:

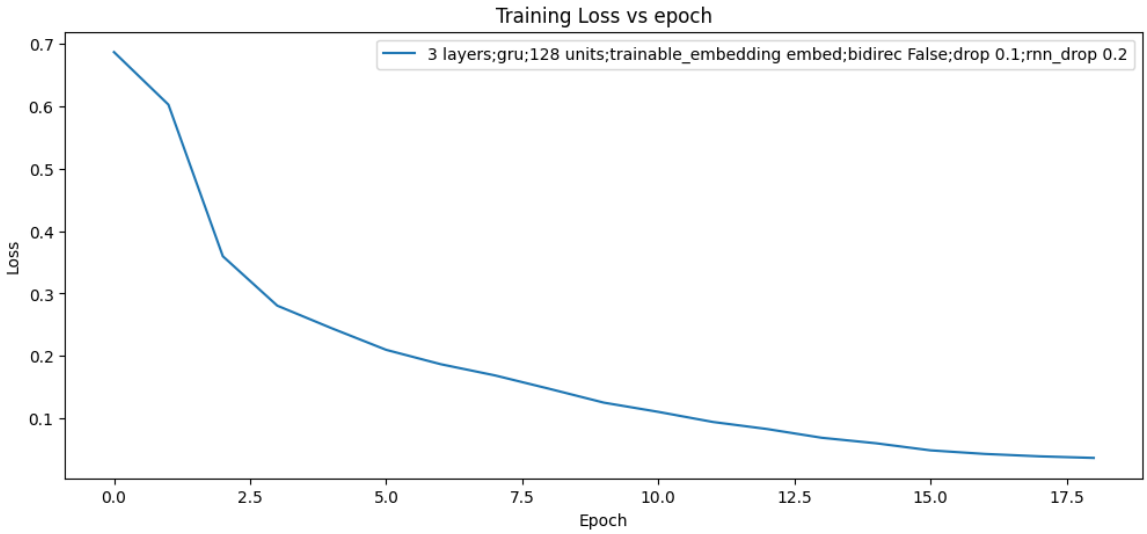
```
0.1
```

# Task 8, 9

In [ ]:

```
# 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_a
cc=0.89;train_time=708.96s;infer_time=1.58s
```




In [ ]:

```
result_df
```

Out[ ]:

| | RNN Type | RNN Layer | RNN Size | Embedding Layer | Bidirectional | RNN Dropout Rate | Dropout Rate | Num Params | Val Loss |
|---|---|---|---|---|---|---|---|---|---|
| **0** | lstm | 1 | 64 | glove | False | 0.0 | 0.0 | 48942 | 0.56954 |
| **1** | gru | 1 | 64 | glove | False | 0.0 | 0.0 | 38574 | 0.28342 |
| **2** | gru | 1 | 32 | glove | False | 0.0 | 0.0 | 16366 | 0.31489 |
| **3** | gru | 1 | 128 | glove | False | 0.0 | 0.0 | 101422 | 0.29255 |
| **4** | gru | 2 | 128 | glove | False | 0.0 | 0.0 | 200494 | 0.31063 |
| **5** | gru | 3 | 128 | glove | False | 0.0 | 0.0 | 299566 | 0.27408 |
| **6** | gru | 4 | 128 | glove | False | 0.0 | 0.0 | 398638 | 0.29677 |
| **7** | gru | 3 | 128 | glove | True | 0.0 | 0.0 | 795438 | 0.29917 |
| **8** | gru | 3 | 128 | glove | False | 0.0 | 0.1 | 299566 | 0.28026 |
| **9** | gru | 3 | 128 | glove | False | 0.2 | 0.0 | 299566 | 0.24916 |
| **10** | gru | 3 | 128 | glove | False | 0.2 | 0.1 | 299566 | 0.24427 |
| **11** | gru | 3 | 128 | trainable_embedding | False | 0.2 | 0.1 | 3150566 | 0.28107 |

In [ ]:

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

best_embedding_layer_type
```

Out[ ]:

```
'glove'
```

# Task 10

In [ ]:

```
result_df
```

Out[ ]:

| | RNN Type | RNN Layer | RNN Size | Embedding Layer | Bidirectional | RNN Dropout Rate | Dropout Rate | Num Params | Val Loss |
|---|---|---|---|---|---|---|---|---|---|
| **0** | lstm | 1 | 64 | glove | False | 0.0 | 0.0 | 48942 | 0.56954 |
| **1** | gru | 1 | 64 | glove | False | 0.0 | 0.0 | 38574 | 0.28342 |
| **2** | gru | 1 | 32 | glove | False | 0.0 | 0.0 | 16366 | 0.31489 |
| **3** | gru | 1 | 128 | glove | False | 0.0 | 0.0 | 101422 | 0.29255 |
| **4** | gru | 2 | 128 | glove | False | 0.0 | 0.0 | 200494 | 0.31063 |
| **5** | gru | 3 | 128 | glove | False | 0.0 | 0.0 | 299566 | 0.27408 |
| **6** | gru | 4 | 128 | glove | False | 0.0 | 0.0 | 398638 | 0.29677 |
| **7** | gru | 3 | 128 | glove | True | 0.0 | 0.0 | 795438 | 0.29917 |
| **8** | gru | 3 | 128 | glove | False | 0.0 | 0.1 | 299566 | 0.28026 |
| **9** | gru | 3 | 128 | glove | False | 0.2 | 0.0 | 299566 | 0.24916 |
| **10** | gru | 3 | 128 | glove | False | 0.2 | 0.1 | 299566 | 0.24427 |
| **11** | gru | 3 | 128 | trainable_embedding | False | 0.2 | 0.1 | 3150566 | 0.28107 |

# Task 11

In [ ]:

```
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
```

In [ ]:

```
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
    )
```

In [ ]:

```
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
```

In [ ]:

```
model.save('best_model')
```

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

WARNING:absl:<keras.layers.recurrent.GRUCell object at 0x7f87c2c56ca
0> has the same name 'GRUCell' as a built-in Keras object. Consider
renaming <class 'keras.layers.recurrent.GRUCell'> to avoid naming co
nflicts when loading with `tf.keras.models.load_model`. If renaming
is not possible, pass the object in the `custom_objects` parameter o
f the load function.
WARNING:absl:<keras.layers.recurrent.GRUCell object at 0x7f87c1f40a6
0> has the same name 'GRUCell' as a built-in Keras object. Consider
renaming <class 'keras.layers.recurrent.GRUCell'> to avoid naming co
nflicts when loading with `tf.keras.models.load_model`. If renaming
is not possible, pass the object in the `custom_objects` parameter o
f the load function.
WARNING:absl:<keras.layers.recurrent.GRUCell object at 0x7f87c39318b
0> has the same name 'GRUCell' as a built-in Keras object. Consider
renaming <class 'keras.layers.recurrent.GRUCell'> to avoid naming co
nflicts when loading with `tf.keras.models.load_model`. If renaming
is not possible, pass the object in the `custom_objects` parameter o
f the load function.
```

In [ ]:

```
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
```

# Task 12

In [ ]:

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

In [ ]:

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

hindi_train_df
```

Out[ ]:

| | text | experience |
|---|---|---|
| **0** | चंद्रमोहन शर्मा को-प्रड्यूसर और लीड ऐक्टर अक्ष... | 2 |
| **1** | अगर आप इस फिल्म को देखने जा रहे हैं तो सबसे पह... | 0 |
| **2** | बॉलीवुड वाले चोरी-छिपे हॉलीवुड फिल्मों से कहान... | 2 |
| **3** | बैनर :\nसंजय दत्त प्रोडक्शन्स प्रा.लि., रुपाली... | 0 |
| **4** | 1959 में घटित चर्चित नानावटी कांड में एक क्राइ... | 1 |
| **...** | ... | ... |
| **713** | 31 अक्टूबर 1984 को काला दिवस कहा जाता है। इस द... | 1 |
| **714** | \n\nगुंडे को देख सत्तर और अस्सी के दशक का सिने... | 1 |
| **715** | Chandermohan.sharma@timesgroup.com ग्लैमर इंडस... | 2 |
| **716** | निर्माता :\nसुनीता गोवारीकर, अजय बिजली, संजीव ... | 2 |
| **717** | फोर्स 2 उन अंडरकवर एजेंट्स को समर्पित है जो सम... | 2 |

718 rows × 2 columns

In [ ]:

```
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
)
```

In [ ]:

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

Out[ ]:

```
['', '[UNK]', 'के', 'है।', 'में']
```

In [ ]:

```
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
```

In [ ]:

```
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()
```

In [ ]:

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

In [ ]:

```
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
_________________________________________________________________
```

In [ ]:

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