Word2Vec

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William Lu

```
import pandas as pd
import numpy as np
import nltk
nltk.download('wordnet')
nltk.download('punkt')
import re
#from bs4 import BeautifulSoup
import contractions
import math
```

```
[nltk_data] Downloading package wordnet to
[nltk_data]     /home1/wlu98761/nltk_data...
[nltk_data]   Package wordnet is already up-to-date!
[nltk_data] Downloading package punkt to /home1/wlu98761/nltk_data...
[nltk_data]   Package punkt is already up-to-date!
```

```
path  = 'amazon_reviews_us_Beauty_v1_00.tsv'
df = pd.read_csv(path,on_bad_lines='skip',sep='\t')
df.head()
```

```
/tmp/SLURM_13907457/ipykernel_8491/3686755405.py:2: DtypeWarning:
Columns (7) have mixed types. Specify dtype option on import or set
low_memory=False.
  df = pd.read_csv(path,on_bad_lines='skip',sep='\t')
```

	marketplace	customer_id	review_id	product_id	product_parent	product_title	product_category
0	US	1797882	R3I2DHQBR577SS	B001ANOOOE	2102612	The Naked Bee Vitmin C Moisturizing Sunscreen ...	Beauty
1	US	18381298	R1QNE9NQFJC2Y4	B0016J22EQ	106393691	Alba Botanica Sunless Tanning Lotion, 4 Ounce	Beauty
2	US	19242472	R3LIDG2Q4LJBAO	B00HU6UQAG	375449471		
3	US	19551372	R3KSZHPAEVPEAL	B002HWS7RM	255651889		
4	US	14802407	RAI2OIG50KZ43	B00SM99KWU	116158747		

```
2          Elysee Infusion Skin Therapy Elixir, 2oz.           Beauty

3  Diane D722 Color, Perm And Conditioner Process...           Beauty

4  Biore UV Aqua Rich Watery Essence SPF50+/PA+++...           Beauty


  star_rating  helpful_votes  total_votes vine verified_purchase  \
0           5            0.0          0.0    N                 Y
1           5            0.0          0.0    N                 Y
2           5            0.0          0.0    N                 Y
3           5            0.0          0.0    N                 Y
4           5            0.0          0.0    N                 Y

                                    review_headline  \
0                                       Five Stars
1                         Thank you Alba Bontanica!
2                                       Five Stars
3                                       GOOD DEAL!
4  this soaks in quick and provides a nice base f...

                                          review_body review_date
0                  Love this, excellent sun block!!  2015-08-31
1  The great thing about this cream is that it do...  2015-08-31
2  Great Product, I'm 65 years old and this is al...  2015-08-31
3  I use them as shower caps & conditioning caps....  2015-08-31
4  This is my go-to daily sunblock. It leaves no ...  2015-08-31
```

```
df2 = df.copy()
dff = df2[['review_body','star_rating']]
#dff['star_rating'] = dff['star_rating'].astype(int)
class_one_score1 = dff.loc[dff['star_rating']=='1']
class_one_score2 = dff.loc[dff['star_rating']=='2']
class_one_label = [class_one_score1,class_one_score2]
class_one =pd.concat(class_one_label,ignore_index=True)
class_one['class_label'] = '1'
class_two_label = dff.loc[dff['star_rating']=='3']
class_two = class_two_label.copy()
class_two['class_label'] = '2'
class_three_score1 = dff.loc[dff['star_rating']=='4']
class_three_score2 = dff.loc[dff['star_rating']=='5']
class_three_label = [class_three_score1,class_three_score2]
class_three =pd.concat(class_three_label,ignore_index=True)
class_three['class_label'] = '3'

# randonly select 20000 rows for each class_label
one = class_one.sample(n = 20000)
two = class_two.sample(n = 20000)
three = class_three.sample(n = 20000)
```

```
# combine the three dataframes together and form a balanced dataset
df_bal_class = [one,two,three]
df_bal = pd.concat(df_bal_class,ignore_index = True)
df_bal
```

```
                                                 review_body
star_rating  \
0      The smell is terrible! I'm not sure if I can k...           1

1               Color doesn't stay on well & looks cheap           2

2      Was small, smelled weird, and also was broken ...           1

3      I don't want this item to have a star it was h...           1

4      I really love this cream/serum! Right when you...           1

...                                                  ...         ...

59995  The smell of this shampoo is amazing. I've tri...           4

59996  After a week I noticed a reduction in hair los...           5

59997                           GOOD VALUE, GOOD PRODUCT           5

59998  Works really well. I use it in the shower and ...           5

59999          Amazing product, personal dentist at home           5


      class_label
0               1
1               1
2               1
3               1
4               1
...           ...
59995           3
59996           3
59997           3
59998           3
59999           3

[60000 rows x 3 columns]
```

```
df_bal2 = df_bal.copy()

# basic data cleaning
df_bal['review_body'] = df_bal['review_body'].astype(str)
# convert all reviews to lowercase
```

```
df_bal['review_body']= df_bal['review_body'].str.lower()
# remove urls from the reviews
df_bal["review_body"] = df_bal["review_body"].str.replace(r'\
s*https?://\S+(\s+|$)', '').str.strip()
# remove htmls tag from the reviews
df_bal['review_body'] = df_bal['review_body'].str.replace(r'<[^<>]*>',
'', regex=True)
# remove numerics
df_bal['review_body'] = df_bal['review_body'].str.replace('\d+',
'',regex=True)
# remove non-alphabetical characters
df_bal['review_body'] = df_bal['review_body'].str.replace('[^a-zA-Z0-
9]', ' ', regex=True)
# perform contractions
df_bal['review_body'] = df_bal['review_body'].apply(lambda x:
contractions.fix(x))
# remove extra space
df_bal['review_body'] = df_bal['review_body'].str.strip()
```

```
/tmp/SLURM_13907457/ipykernel_8491/3100350469.py:6: FutureWarning: The
default value of regex will change from True to False in a future
version.
  df_bal["review_body"] = df_bal["review_body"].str.replace(r'\
s*https?://\S+(\s+|$)', '').str.strip()
```

```
df_bal
```

	review_body	star_rating
0	the smell is terrible i m not sure if i can k...	1
1	color doesn t stay on well looks cheap	2
2	was small smelled weird and also was broken ...	1
3	i don t want this item to have a star it was h...	1
4	i really love this cream serum right when you...	1
...	...	...
59995	the smell of this shampoo is amazing i ve tri...	4
59996	after a week i noticed a reduction in hair los...	5
59997	good value good product	5
59998	works really well i use it in the shower and ...	5
59999	amazing product personal dentist at home	5

```
      class_label
0               1
1               1
2               1
3               1
4               1
...           ...
59995           3
59996           3
59997           3
59998           3
59999           3

[60000 rows x 3 columns]
```

2. Word Embeddings using Gensim Libarary

Word2Vec is a more recent model that embeds words in a lower-dimensional vector space using a shallow neural network. The result is a set of word-vectors where vectors close together in vector space have similar meanings based on context, and word-vectors distant to each other have differing meanings.

https://radimrehurek.com/gensim/auto_examples/tutorials/run_word2vec.html

(a) Figuring out how to extract word embedding. Check semantic similarities of generated vectors.

```
import gensim.downloader as api
import gensim
from gensim.models import Word2Vec
from nltk import word_tokenize
wv = api.load('word2vec-google-news-300')

# more cleaning here to make sure no space between each word
df_text = df_bal["review_body"]
df_text = list(df_text)
df_text = [' '.join(text.split()) for text in df_text]

# tokenize the text to words so that we can do word2vec
df_text_tokenized = []
for text in df_text:
    temp = word_tokenize(text)
    df_text_tokenized.append(temp)

df_text_tokenized[1]
```

```
['color', 'doesn', 't', 'stay', 'on', 'well', 'looks', 'cheap']
```

```
w1 = "outstanding"
w2 = "excellent"
```

```
w3 = "car"
w4 = "train"
w5 = "university"
w6 = "college"
example1 = wv.similarity(w1, w2)
example2 = wv.similarity(w3, w4)
example3 = wv.similarity(w5, w6)
# example1_similar_words = wv.most_similar(positive=[w1,w2],topn=1)
# I could not use this most_similar since I'm using colab. It crashes
and one post @528 says we can just use
# the wv.similarity
print(f"The semantic similarity between {w1} and {w2} is: ", example1)
print(f"The semantic similarity between {w3} and {w4} is: ", example2)
print(f"The semantic similarity between {w5} and {w6} is: ", example3)
# print(f"The most similar word compared to {w1} and {w2} is: ",
example1_similar_words)
```

```
The semantic similarity between outstanding and excellent is:
0.55674857
The semantic similarity between car and train is:  0.3402561
The semantic similarity between university and college is:  0.6385269
```

reference: https://radimrehurek.com/gensim/models/word2vec.html

(b) Train a word2vec model

The text below is just for studying purposes.

"size: The number of dimensions of the embeddings and the default is 100.

window: The maximum distance between a target word and words around the target word. The default window is 5.

min_count: The minimum count of words to consider when training the model; words with occurrence less than this count will be ignored. The default for min_count is 5.

workers: The number of partitions during training and the default workers is 3.

sg: The training algorithm, either CBOW(0) or skip gram(1). The default training algorithm is CBOW."

https://towardsdatascience.com/a-beginners-guide-to-word-embedding-with-gensim-word2vec-model-5970fa56cc92

```
my_w2v =
Word2Vec(df_text_tokenized,min_count=9,vector_size=300,window=13,worke
rs=3,sg=1)
my_w2v.save("word2vec_amazon.model")
```

Check the semantic similarities for the 2 examples

```
model1 = gensim.models.Word2Vec.load("word2vec_amazon.model")
```

```
my_model_example1_similarity = model1.wv.similarity(w1,w2)
my_model_example2_similarity = model1.wv.similarity(w3,w4)
#my_model_example3_similarity = my_w2v.similarity(w5,w6)
print(f"The semantic similarity between {w1} and {w2} from my w2v
model is: ", my_model_example1_similarity)
print(f"The semantic similarity between {w3} and {w4} from my w2v
model is: ", my_model_example2_similarity)
#print(f"The semantic similarity between {w5} and {w6} from my w2v
model is: ", my_model_example3_similarity)
```

```
The semantic similarity between outstanding and excellent from my w2v
model is:  0.48570466
The semantic similarity between car and train from my w2v model is:
0.48843965
```

Now we use CBOW as the training algorithm.

```
my_w2v_2 =
Word2Vec(df_text_tokenized,min_count=9,vector_size=300,window=13,worke
rs=3,sg=0)
my_w2v_2.save("word2vec_amazon2.model")
```

```
model2 = gensim.models.Word2Vec.load("word2vec_amazon2.model")
```

```
my_model_example1_similarity2 = model2.wv.similarity(w1,w2)
my_model_example2_similarity2 = model2.wv.similarity(w3,w4)
```

```
print(f"The semantic similarity between {w1} and {w2} from my second
w2v model is: ", my_model_example1_similarity2)
print(f"The semantic similarity between {w3} and {w4} from my second
w2v model is: ", my_model_example2_similarity2)
```

```
The semantic similarity between outstanding and excellent from my
second w2v model is:  0.67975754
The semantic similarity between car and train from my second w2v model
is:  0.15224382
```

```
print(wv.most_similar('outstanding'))
```

```
[('oustanding', 0.8012188673019409), ('Outstanding',
0.6041857600212097), ('exceptional', 0.6031844615936279),
('anchorman_Jason_Lezak', 0.5947381258010864), ('outsanding',
0.566262423992157), ('Stock_HEI', 0.5573362708091736), ('excellent',
0.556748628616333), ('Synplicity_FPGA_implementation',
0.5520347356796265), ('exemplary', 0.5467386245727539),
('W3_Awards_honors', 0.5172522068023682)]
```

```
print(wv.most_similar_cosmul(positive=
['king','woman'],negative=['man'], topn= 1))
```

```
[('queen', 0.9314123392105103)]
```

Comparing the model generated by myself and the pretained model, I think my the pretrained model describes the similarity between two words better. I also conclude that not all the words from the pretained model are in the model I train. In other words, my trained features mainly are about reviews. Some words do not often appear in reveiws.

3. Use Google pre-trained W2V features to train a single perceptron model and an SVM model

Split the data into training and testing.

```
from sklearn.model_selection import train_test_split
```

```
def vector_average(x,w):
    temp = np.zeros(300)
    n=0
    for word in x:
        if word in w:
            n+=1
            temp+=w[word]
    if n>0:
        return temp/n
    else:
        return temp
```

```
#df_bal["tokenized"]= df_bal.apply(lambda x:
word_tokenize(x['review_body']), axis=1)
df_bal["cleaned_tokenized"] = df_text_tokenized
```

```
df_bal["vector"]=df_bal["cleaned_tokenized"].apply(lambda
x:vector_average(x,wv))
```

```
df_bal["vector"]
```

```
0        [0.017755126953125, 0.019000244140625, 0.04739...
1        [-0.016933441162109375, 0.07696533203125, -0.1...
2        [0.06226399739583333, 0.025470542907714843, 0....
3        [0.01211270419034091, 0.07297784631902521, 0.0...
4        [0.01719908783401268, 0.026452299477397533, 0....
                                ...
59995    [0.03624439239501953, 0.034887611865997314, 0....
59996    [-0.029820033482142856, 0.07513776506696429, 0...
59997    [0.0247802734375, 0.05975341796875, 0.05206298...
59998    [-0.02181827320772059, 0.10931834052590762, 0....
59999    [0.02679443359375, 0.017664591471354168, 0.006...
Name: vector, Length: 60000, dtype: object
```

```
temp = 300
for i in df_bal["vector"]:
    if len(i)<temp:
        temp = len(i)
print(temp)
```

```
300
```

```
df_bal["class_label"] = pd.to_numeric(df_bal["class_label"])
```

Perceptron (pass in the features into the model)

```
X_train,X_test,y_train,y_test =
train_test_split(list(df_bal["vector"]),df_bal["class_label"],test_siz
e = 0.2,random_state=42)
y_train = y_train.values
y_test = y_test.values
```

```
from sklearn.linear_model import Perceptron
from sklearn.metrics import accuracy_score, precision_score,
recall_score
perceptron = Perceptron()
perceptron.fit(list(X_train),y_train)
y_pred_perceptron = perceptron.predict(X_test)
```

```
acc_score_w2v_perceptron = accuracy_score(y_pred_perceptron,y_test)
print("Accuracy score for the perceptron model using word2vec-google-
news-300 features is: ",acc_score_w2v_perceptron)
```

```
Accuracy score for the perceptron model using word2vec-google-news-300
features is:  0.57025
```

```
from sklearn.svm import LinearSVC
svm = LinearSVC()
svm.fit(X_train,y_train)
y_pred_svm = svm.predict(X_test)
```

```
acc_score_w2v_svm = accuracy_score(y_pred_svm,y_test)
```

```
print("Accuracy score for the SVM model using word2vec-google-news-300
features is: ",acc_score_w2v_svm)
```

```
Accuracy score for the SVM model using word2vec-google-news-300
features is:  0.6745
```

For using TF-IDF features, we can just report the accuracy from HW1 according to post @569 on Piazza.

```
print("Accuracy score for the perceptron model using TF-IDF features
is: ",0.61)
print("Accuracy score for the SVM model using TF-IDF features is:
",0.67)
```

```
Accuracy score for the perceptron model using TF-IDF features is:
0.61
Accuracy score for the SVM model using TF-IDF features is:  0.67
```

So we can conclude that using word2vec features as input can help us achieve a higher accuracy score than using TF-IDF. Especially for the perceptron model.

4. Feedforward Neural Networks

Using the Word2Vec features, train a feedforward multilayer perceptron network for classification. Consider a network with two hidden layers, each with 100 and 10 nodes, respectively. You can use cross entropy loss and your own choice for other hyperparamters.

You can use cross entropy loss and your own choice for other hyperparamters, e.g., nonlinearity, number of epochs

reference: https://www.kaggle.com/code/mishra1993/pytorch-multi-layer-perceptron-mnist/notebook

(a) Use the average Word2Vec vectors to generate the input features

```
import torch
from torch.utils.data import DataLoader, Dataset
import torchvision.transforms as transforms
```

```
/home1/wlu98761/.conda/envs/tweet_capture_env/lib/python3.10/site-
packages/tqdm/auto.py:22: TqdmWarning: IProgress not found. Please
update jupyter and ipywidgets. See
https://ipywidgets.readthedocs.io/en/stable/user_install.html
  from .autonotebook import tqdm as notebook_tqdm
```

```
import torch.nn as nn
import torchvision
from torch.utils.data.sampler import SubsetRandomSampler
import torch.nn.functional as F
from torch.utils.data import TensorDataset, DataLoader, Dataset
from torch import optim
```

```
class Net1(nn.Module):
    def __init__(self):
        super(Net1,self).__init__()
        hidden_layer1 = 100
        hidden_layer2 = 10
        self.fc1 = nn.Linear(300,hidden_layer1)
        self.fc2 = nn.Linear(hidden_layer1,hidden_layer2)
        self.fc3 = nn.Linear(hidden_layer2,3)
        self.dropout = nn.Dropout(0.2)
    def forward(self,x):
        x = F.relu(self.fc1(x))
        x = self.dropout(x)
        x = F.relu(self.fc2(x))
        x = self.dropout(x)
        x = self.fc3(x)
        return x

FNN = Net1()
print(FNN)
```

```
Net1(
  (fc1): Linear(in_features=300, out_features=100, bias=True)
  (fc2): Linear(in_features=100, out_features=10, bias=True)
  (fc3): Linear(in_features=10, out_features=3, bias=True)
  (dropout): Dropout(p=0.2, inplace=False)
)
```

```
# Specify Loss Function and Optimizer
# Categorical cross-entropy
criterion = nn.CrossEntropyLoss()
# Optimizer
optimizer = optim.Adam(FNN.parameters(),lr=0.001)

#X_train_FNN = torch.Tensor(X_train)
#X_test_FNN = torch.Tensor(X_test)
y_train_tensor = torch.LongTensor(y_train-1)
y_test_tensor = torch.LongTensor(y_test-1)

num_epoch = 50
for epoch in range(num_epoch):
    y_pred_FNN = FNN(torch.from_numpy(np.asarray(X_train)).float())
    loss_FNN = criterion(y_pred_FNN,y_train_tensor)
    print("Epoch {} \ttraining loss: {:.6f}".format(epoch+1,loss_FNN))
    optimizer.zero_grad()
    # backward pass
    loss_FNN.backward()
    optimizer.step()
```

```
Epoch 1    training loss: 1.128162
Epoch 2    training loss: 1.126405
Epoch 3    training loss: 1.124433
Epoch 4    training loss: 1.122028
Epoch 5    training loss: 1.119618
Epoch 6    training loss: 1.117301
Epoch 7    training loss: 1.115233
Epoch 8    training loss: 1.112937
Epoch 9    training loss: 1.110993
Epoch 10   training loss: 1.108657
Epoch 11   training loss: 1.106557
Epoch 12   training loss: 1.104561
Epoch 13   training loss: 1.102927
Epoch 14   training loss: 1.100927
Epoch 15   training loss: 1.098952
Epoch 16   training loss: 1.097641
Epoch 17   training loss: 1.096733
Epoch 18   training loss: 1.094750
Epoch 19   training loss: 1.093542
Epoch 20   training loss: 1.092620
Epoch 21   training loss: 1.090882
Epoch 22   training loss: 1.089286
Epoch 23   training loss: 1.086766
```

```
Epoch 24   training loss: 1.085494
Epoch 25   training loss: 1.083333
Epoch 26   training loss: 1.081580
Epoch 27   training loss: 1.078220
Epoch 28   training loss: 1.077083
Epoch 29   training loss: 1.075523
Epoch 30   training loss: 1.072357
Epoch 31   training loss: 1.069890
Epoch 32   training loss: 1.066930
Epoch 33   training loss: 1.064958
Epoch 34   training loss: 1.062240
Epoch 35   training loss: 1.059295
Epoch 36   training loss: 1.057083
Epoch 37   training loss: 1.054626
Epoch 38   training loss: 1.050888
Epoch 39   training loss: 1.048146
Epoch 40   training loss: 1.044634
Epoch 41   training loss: 1.041597
Epoch 42   training loss: 1.038586
Epoch 43   training loss: 1.035167
Epoch 44   training loss: 1.031631
Epoch 45   training loss: 1.029202
Epoch 46   training loss: 1.025535
Epoch 47   training loss: 1.021495
Epoch 48   training loss: 1.019515
Epoch 49   training loss: 1.014703
Epoch 50   training loss: 1.010694
```

```
y_pred_FNN =
np.array(FNN(torch.from_numpy(np.asarray(X_test)).float()).argmax(axis
=1))
counter = 0
for i in range(0,len(y_pred_FNN)):
    if y_pred_FNN[i]+1 ==y_test[i]:
        counter += 1 # find the number of correct predictions
print("The accuracy for Feedforward Neural Networks by using word2vec-
google-news-300 is:", counter/len(y_pred_FNN))
```

```
The accuracy for Feedforward Neural Networks by using word2vec-google-
news-300 is: 0.525
```

```
y_pred_FNN
```

```
array([1, 0, 0, ..., 2, 2, 1])
```

```
y_test
```

```
array([1, 2, 2, ..., 3, 2, 2])
```

(b) Concatethe first 10 Word2Vec vectors for each review to generate input features

```
df_text2 = df_bal["review_body"]
df_text2 = list(df_text2)
df_text2 = [' '.join(text.split()) for text in df_text]
df_bal["non space text"] = df_text2
```

```
df_bal["non space text"]
```

```
0        the smell is terrible i m not sure if i can ke...
1                    color doesn t stay on well looks cheap
2        was small smelled weird and also was broken ei...
3        i don t want this item to have a star it was h...
4        i really love this cream serum right when you ...
                               ...
59995    the smell of this shampoo is amazing i ve trie...
59996    after a week i noticed a reduction in hair los...
59997                              good value good product
59998    works really well i use it in the shower and a...
59999              amazing product personal dentist at home
Name: non space text, Length: 60000, dtype: object
```

```
X_train_10,X_test_10,Y_train_10,Y_test_10 =
train_test_split(df_bal["non space
text"],df_bal["class_label"].values, test_size = 0.2,random_state=42)
```

```
X_train_10
```

```
48572                                      amazing product
38696                                 it s ok for the price
13611    came in early shiny blah blah it was broken an...
35213    i was looking for more like a nars orgasm knoc...
31766    this is soft and won t dry out your lips but i...
                               ...
54343                                what a fantastic scent
38158    eh nothing astoundingly delicious in this coll...
860                you must be kidding use for how you wen
15795    mah on my hunt for hair product that does not ...
56422    color turned out perfect and it did not ruin m...
Name: non space text, Length: 48000, dtype: object
```

```
def tokenize(temp):
# For each sentence, word tokenization is performed using NLTK
    result = [word_tokenize(sentence) for sentence in temp]
    return result

def word_embed_10(x, m):
    X=[]
    vecs =[]
    for w in x:
        if w in m:
            vecs.append(m[w])
    while len(vecs) < 10:
        vecs.append(np.zeros(300))
```

```
    X.append(np.concatenate(vecs[:10]))
    return X

df_text10 = list(X_train_10)
df_text10 = [' '.join(text.split()) for text in df_text10]
df_text_tokenized10_train = []
for text in df_text10:
    temp = word_tokenize(text)
    df_text_tokenized10_train.append(temp)

df_text_tokenized10_train_em=[word_embed_10(x,wv) for x in
df_text_tokenized10_train]

df_text10_test = list(X_test_10)
df_text10_test = [' '.join(text.split()) for text in df_text10_test]
df_text_tokenized10_test = []
for text in df_text10_test:
    temp = word_tokenize(text)
    df_text_tokenized10_test.append(temp)

df_text_tokenized10_test_em=[word_embed_10(x,wv) for x in
df_text_tokenized10_test]

Y_train_10

array([3, 2, 1, ..., 1, 1, 3])

Y_train_10_tensor

tensor([2, 1, 0,  ..., 0, 0, 2])

df_text_tokenized10_train_em

[[array([ 0.07373047,  0.00405884, -0.13574219, ...,  0.        ,
          0.        ,  0.        ])],
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          0.        ,  0.        ])],
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         -0.0378418 , -0.15136719], dtype=float32)],
 [array([-0.22558594, -0.01953125,  0.09082031, ...,  0.01708984,
          0.06079102, -0.10888672], dtype=float32)],
 [array([ 0.109375  ,  0.140625  , -0.03173828, ..., -0.05566406,
          0.10498047, -0.10839844], dtype=float32)],
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          0.        ,  0.        ])],
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,
         0.        ])],
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```

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```
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df_text_tokenized10_test_em

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          0.04760742, -0.06884766], dtype=float32)],
 [array([ 0.04052734,  0.0625    , -0.01745605, ...,  0.02844238,
         -0.09960938,  0.0324707 ], dtype=float32)],
 [array([ 0.03881836, -0.06640625, -0.09423828, ...,  0.        ,
          0.        ,  0.        ])],
 [array([-0.22558594, -0.01953125,  0.09082031, ...,  0.06005859,
          0.07128906, -0.05834961], dtype=float32)],
 [array([ 0.08447266, -0.00035286,  0.05322266, ...,  0.        ,
          0.        ,  0.        ])],
 [array([ 0.02600098, -0.00189209,  0.18554688, ...,  0.00366211,
          0.04760742, -0.06884766], dtype=float32)],
 [array([ 0.03930664, -0.0057373 , -0.09033203, ..., -0.09814453,
          0.21777344,  0.02185059], dtype=float32)],
 [array([ 0.14453125,  0.04711914,  0.10058594, ...,  0.01708984,
          0.06079102, -0.10888672], dtype=float32)],
 [array([ 0.08447266, -0.00035286,  0.05322266, ..., -0.29882812,
         -0.01104736, -0.3203125 ], dtype=float32)],
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         -0.04321289,  0.01635742], dtype=float32)],
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          0.        ,  0.        ])],
 [array([ 0.00193787, -0.00878906, -0.01385498, ...,  0.        ,
          0.        ,  0.        ])],
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          0.06079102, -0.10888672], dtype=float32)],
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         -0.09960938,  0.0324707 ], dtype=float32)],
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         -0.00970459, -0.09570312], dtype=float32)],
 [array([ 0.00946045,  0.14160156, -0.0546875 , ..., -0.12988281,
         -0.13964844,  0.17382812], dtype=float32)],
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          0.19628906, -0.11474609], dtype=float32)],
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         -0.02990723,  0.27539062], dtype=float32)],
 [array([ 0.109375  ,  0.140625  , -0.03173828, ...,  0.        ,
          0.        ,  0.        ])],
 [array([ 0.14453125,  0.04711914,  0.10058594, ..., -0.22949219,
         -0.00970459, -0.09570312], dtype=float32)],
 [array([ 0.04052734,  0.0625    , -0.01745605, ...,  0.        ,
          0.        ,  0.        ])],
 [array([-0.22558594, -0.01953125,  0.09082031, ..., -0.17480469,
         -0.02307129, -0.04345703], dtype=float32)],
```

```
 [array([-0.22558594, -0.01953125,  0.09082031, ...,  0.00686646,
         0.06103516, -0.1484375 ], dtype=float32)],
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         0.        ,  0.        ])],
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 [array([ 0.109375  ,  0.140625  , -0.03173828, ...,  0.        ,
         0.        ,  0.        ])],
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         0.        ,  0.        ])],
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        -0.265625  , -0.10058594], dtype=float32)],
 [array([ 0.10107422, -0.0038147 ,  0.01818848, ...,  0.        ,
         0.        ,  0.        ])],
 [array([-0.22558594, -0.01953125,  0.09082031, ...,  0.10742188,
         0.06152344, -0.30859375], dtype=float32)],
 [array([-0.03393555,  0.16015625,  0.12060547, ...,  0.        ,
         0.        ,  0.        ])],
 [array([ 0.01159668,  0.21679688,  0.14746094, ..., -0.04443359,
         0.01379395, -0.03808594], dtype=float32)],
 [array([ 0.109375  ,  0.140625  , -0.03173828, ..., -0.06738281,
        -0.09912109, -0.1640625 ], dtype=float32)],
 [array([ 0.04052734,  0.0625    , -0.01745605, ...,  0.01434326,
         0.1484375 , -0.03833008], dtype=float32)],
 [array([ 0.14453125,  0.04711914,  0.10058594, ...,  0.0625    ,
         0.24023438, -0.10253906], dtype=float32)],
 [array([ 0.12451172,  0.09082031, -0.00488281, ...,  0.        ,
         0.        ,  0.        ])],
 [array([0.06445312, 0.03613281, 0.03857422, ..., 0.        , 0.
,
        0.        ])],
 [array([ 0.08447266, -0.00035286,  0.05322266, ..., -0.17480469,
        -0.02307129, -0.04345703], dtype=float32)],
 [array([ 0.07177734,  0.20800781, -0.02844238, ...,  0.        ,
         0.        ,  0.        ])],
 [array([-0.06152344,  0.09521484,  0.13378906, ..., -0.08203125,
        -0.08300781, -0.01361084], dtype=float32)],
 [array([-0.0703125 ,  0.09179688,  0.14453125, ..., -0.05078125,
         0.0234375 , -0.09130859], dtype=float32)],
 [array([-0.22558594, -0.01953125,  0.09082031, ...,  0.03881836,
         0.15234375, -0.02685547], dtype=float32)],
 [array([-0.22558594, -0.01953125,  0.09082031, ...,  0.44335938,
         0.19921875, -0.12890625], dtype=float32)],
 [array([ 0.02429199,  0.01080322, -0.10742188, ...,  0.        ,
         0.        ,  0.        ])],
 ...]
```

```
Y_train_10_tensor= torch.LongTensor(Y_train_10-1)
Y_test_10_tensor= torch.LongTensor(Y_test_10-1)

class Net_10(nn.Module):
    def __init__(self):
        super(Net_10, self).__init__()
        hidden_1 = 100
        hidden_2 = 10
        self.fc1 = nn.Linear(300*10, hidden_1)
        self.fc2 = nn.Linear(hidden_1, hidden_2)
        self.fc3 = nn.Linear(hidden_2, 3)
        self.dropout = nn.Dropout(0.2)

    def forward(self, x):
        x = x.view(-1, 300*10)
        x = F.relu(self.fc1(x))
        x = self.dropout(x)
        x = F.relu(self.fc2(x))
        x = self.dropout(x)
        x = self.fc3(x)
        return x

model_FNN_10 = Net_10()
print(model_ternary3)

TernaryNet_10(
  (fc1): Linear(in_features=3000, out_features=100, bias=True)
  (fc2): Linear(in_features=100, out_features=10, bias=True)
  (fc3): Linear(in_features=10, out_features=3, bias=True)
  (dropout): Dropout(p=0.2, inplace=False)
)

num_epoch = 100
for epoch in range(num_epoch):
    y_pred_FNN_10 =
model_FNN_10(torch.from_numpy(np.asarray(df_text_tokenized10_train_em)
).float())
    loss_FNN_10 = criterion(y_pred_FNN_10,Y_train_10_tensor)
    print("Epoch {} \ttraining loss:
{:.6f}".format(epoch+1,loss_FNN_10))
    optimizer.zero_grad()
    # backward pass
    loss_FNN_10.backward()
    optimizer.step()

Epoch 1    training loss: 1.124599
Epoch 2    training loss: 1.124601
Epoch 3    training loss: 1.124624
Epoch 4    training loss: 1.124595
Epoch 5    training loss: 1.124610
Epoch 6    training loss: 1.124606
```

```
Epoch 7    training loss: 1.124615
Epoch 8    training loss: 1.124616
Epoch 9    training loss: 1.124602
Epoch 10   training loss: 1.124603
Epoch 11   training loss: 1.124589
Epoch 12   training loss: 1.124602
Epoch 13   training loss: 1.124598
Epoch 14   training loss: 1.124576
Epoch 15   training loss: 1.124602
Epoch 16   training loss: 1.124610
Epoch 17   training loss: 1.124584
Epoch 18   training loss: 1.124615
Epoch 19   training loss: 1.124600
Epoch 20   training loss: 1.124617
Epoch 21   training loss: 1.124622
Epoch 22   training loss: 1.124607
Epoch 23   training loss: 1.124630
Epoch 24   training loss: 1.124595
Epoch 25   training loss: 1.124612
Epoch 26   training loss: 1.124586
Epoch 27   training loss: 1.124602
Epoch 28   training loss: 1.124591
Epoch 29   training loss: 1.124583
Epoch 30   training loss: 1.124613
Epoch 31   training loss: 1.124612
Epoch 32   training loss: 1.124622
Epoch 33   training loss: 1.124601
Epoch 34   training loss: 1.124587
Epoch 35   training loss: 1.124601
Epoch 36   training loss: 1.124588
Epoch 37   training loss: 1.124611
Epoch 38   training loss: 1.124591
Epoch 39   training loss: 1.124596
Epoch 40   training loss: 1.124621
Epoch 41   training loss: 1.124605
Epoch 42   training loss: 1.124614
Epoch 43   training loss: 1.124590
Epoch 44   training loss: 1.124582
Epoch 45   training loss: 1.124610
Epoch 46   training loss: 1.124585
Epoch 47   training loss: 1.124594
Epoch 48   training loss: 1.124587
Epoch 49   training loss: 1.124576
Epoch 50   training loss: 1.124583
Epoch 51   training loss: 1.124593
Epoch 52   training loss: 1.124611
Epoch 53   training loss: 1.124602
Epoch 54   training loss: 1.124614
Epoch 55   training loss: 1.124602
Epoch 56   training loss: 1.124584
```

```
Epoch 57   training loss: 1.124600
Epoch 58   training loss: 1.124614
Epoch 59   training loss: 1.124593
Epoch 60   training loss: 1.124602
Epoch 61   training loss: 1.124606
Epoch 62   training loss: 1.124603
Epoch 63   training loss: 1.124578
Epoch 64   training loss: 1.124609
Epoch 65   training loss: 1.124610
Epoch 66   training loss: 1.124629
Epoch 67   training loss: 1.124607
Epoch 68   training loss: 1.124612
Epoch 69   training loss: 1.124603
Epoch 70   training loss: 1.124602
Epoch 71   training loss: 1.124621
Epoch 72   training loss: 1.124619
Epoch 73   training loss: 1.124601
Epoch 74   training loss: 1.124614
Epoch 75   training loss: 1.124623
Epoch 76   training loss: 1.124596
Epoch 77   training loss: 1.124626
Epoch 78   training loss: 1.124600
Epoch 79   training loss: 1.124586
Epoch 80   training loss: 1.124608
Epoch 81   training loss: 1.124615
Epoch 82   training loss: 1.124597
Epoch 83   training loss: 1.124603
Epoch 84   training loss: 1.124617
Epoch 85   training loss: 1.124599
Epoch 86   training loss: 1.124612
Epoch 87   training loss: 1.124602
Epoch 88   training loss: 1.124617
Epoch 89   training loss: 1.124610
Epoch 90   training loss: 1.124620
Epoch 91   training loss: 1.124589
Epoch 92   training loss: 1.124607
Epoch 93   training loss: 1.124602
Epoch 94   training loss: 1.124617
Epoch 95   training loss: 1.124606
Epoch 96   training loss: 1.124614
Epoch 97   training loss: 1.124588
Epoch 98   training loss: 1.124570
Epoch 99   training loss: 1.124594
Epoch 100  training loss: 1.124621
```

```
y_pred_FNN_10 =
np.array(model_FNN_10(torch.from_numpy(np.asarray(df_text_tokenized10_
test_em)).float()).argmax(axis=1))
counter_10 = 0
for i in range(0,len(y_pred_FNN_10)):
```

```
    if y_pred_FNN_10[i]+1==Y_test_10_tensor[i]:
        counter_10 += 1 # find the number of correct predictions
print("The accuracy for Feedforward Neural Networks by using word2vec-
google-news-300 and concatenating first 10 words is:",
counter_10/6000)
```

```
The accuracy for Feedforward Neural Networks by using word2vec-google-
news-300 and concatenating first 10 words is: 0.669
```

I can conclude that using average word2vec FNN is better. It is similar to SVM and Perceptron accuracy. If concatenating the first 10 words, the accuracy is close to using the average word2vec features.

5. Recurrent Neural Networks

reference:
https://pytorch.org/tutorials/intermediate/char_rnn_classification_tutorial.html

(a) Train RNN for sentiment analysis. Hidden state size = 20

```
from torch.nn.utils.rnn import pad_sequence

def word_embed_2(review, m):
    doc = []
    n = 0
    for r in review:
        if r in m:
            n += 1
            doc.append(m[r])
            if n==20:
                break
    while n!=20:
        doc.append(np.zeros(300))
        n += 1
    return doc

def word_embedding(review):
    doc = []
    for r in review:
        doc.append([wv.key_to_index[word] if word in wv.key_to_index
else 0 for word in r])
    return doc

x_train3,x_test3,y_train3,y_test3 =
train_test_split(df_bal["review_body"],df_bal["class_label"].values,
test_size = 0.2,random_state=42)

x_train3_tok = tokenize(x_train3)
x_test3_tok = tokenize(x_test3)

def padding(x,length):
    for i, j in enumerate(x):
```

```
        if len(j) >length:
            x[i] = j[:length]
        elif len(j)<length:
            x[i] = j[:len(j)]+[0]*(length-len(j))
    return x

new_x_train3_tok_em = word_embedding(x_train3_tok)
new_x_test3_tok_em = word_embedding(x_test3_tok)

new_x_train3_tok_em = np.array(padding(new_x_train3_tok_em,20))
new_x_test3_tok_em = np.array(padding(new_x_test3_tok_em,20))

xx_train3 = torch.LongTensor(new_x_train3_tok_em)
xx_test3 = torch.LongTensor(new_x_test3_tok_em)
yy_train3 = torch.LongTensor(y_train3-1)
yy_test3 = torch.LongTensor(y_test3-1)

Train3 = TensorDataset(xx_train3,yy_train3)
Test3 = TensorDataset(xx_test3,yy_test3)

load_Train3 = DataLoader(Train3, batch_size=32,shuffle=True)
load_Test3 = DataLoader(Test3, batch_size =32, shuffle =False)

yy_test3

tensor([0, 1, 1,  ..., 2, 1, 1])

input_size = len(wv)+1
hidden_size = 20
num_layers = 20
output_size = 1
from tqdm import tqdm
from torch.nn.utils.rnn import pack_padded_sequence
from torch.nn.utils.rnn import pad_packed_sequence
class RNN(nn.Module):
    def __init__(self, input_size, hidden_size, num_layers,
class_num):
        super(RNN, self).__init__()
        self.hidden_size = hidden_size
        self.embedding = nn.Embedding(input_size,num_layers)
        self.rnn = nn.RNN(num_layers, hidden_size, batch_first=True,
nonlinearity="relu")
        self.fc = nn.Linear(hidden_size, class_num)

    def forward(self, x):
        # initize the hidden layer
        embedded_x = self.embedding(x)
        out, _ = self.rnn(embedded_x)
        output = self.fc(out)
        return output

model_RNN =  RNN(input_size,num_layers,hidden_size,output_size)
```

```
model_RNN
```

```
RNN(
  (embedding): Embedding(3000001, 20)
  (rnn): RNN(20, 20, batch_first=True)
  (fc): Linear(in_features=20, out_features=1, bias=True)
)
```

```
loss_RNN = nn.CrossEntropyLoss()
optimizer_RNN = optim.Adam(model_RNN.parameters(),lr=0.001)
```

```
# help from peers
def training(model,epoch,batch_size,loader,optimizer,loss):
    model.train()
    loss_epoch= 0
    for i, j in loader:
        optimizer.zero_grad()
        output = model(i)
        loss_per_epoch = loss(output,j.reshape(1,batch_size).t())
        loss_per_epoch.backward()
        optimizer.step()
        loss_epoch+=loss_per_epoch.item()
    print("Accuracy:{:.6f}".format(loss_per_epoch.item()))
```

```
# help from peers
def testing(model,test_loader):
    model.eval()
    correct = 0
    with torch.no_grad():
        for i, t in test_loader:
            output = model(i)
            _, predicted = torch.max(output.data, 1)
            correct += predicted.eq(t.data.view_as(predicted)).sum()

    data_num = len(test_loader.dataset)
    print('\nAccuracy with test data is {}'.format(correct /
data_num))
```

```
for epoch in range(5):
    training(model_RNN,epoch,32,load_Train3,optimizer_RNN,loss_RNN)
testing(model_RNN, load_Test3)
```

```
Accuracy:0.952885
Accuracy:0.817868
Accuracy:1.027247
Accuracy:0.665553
Accuracy:0.946841
```

```
---------------------------------------------------------------------------
-----
NameError                                 Traceback (most recent call
last)
```

```
Cell In [167], line 3
      1 for epoch in range(5):
      2
training(model_RNN,epoch,32,load_Train3,optimizer_RNN,loss_RNN)
----> 3 testing(model_RNN, load_Test3)

Cell In [166], line 6, in testing(model, test_loader)
      4 with torch.no_grad():
      5     for i, t in test_loader:
----> 6         output = model(data)
      7         _, predicted = torch.max(output.i, 1)
      8         correct += predicted.eq(t.i.view_as(predicted)).sum()

NameError: name 'data' is not defined
```

Please ignore the pink area. I move the testing to below. I don't want to erase the result since it takes too long to run this cell.

```
testing(model_RNN, load_Test3)
```

```
Accuracy with test data is 0.5632500052452087
```

refence: https://pytorch.org/docs/stable/generated/torch.t.html#:~:text=Expects%20input%20to%20be%20%3C%3D%202,input%2C%200%2C%201)%20.
https://discuss.pytorch.org/t/valueerror-expected-input-batch-size-324-to-match-target-batch-size-4/24498/9

(b) GRU

```
class GRU(nn.Module):
    def __init__(self, input_size, hidden_size, num_layers,
class_num):
        super(RNN, self).__init__()
        self.hidden_size = hidden_size
        self.embedding = nn.Embedding(input_size,num_layers)
        self.rnn = nn.GRU(num_layers, hidden_size, batch_first=True)
        self.fc = nn.Linear(hidden_size, class_num)

    def forward(self, x):
        # initize the hidden layer
        embedded_x = self.embedding(x)
        out, _ = self.gru(embedded_x)
        output = self.fc(out)
        return output

model_GRU =  RNN(input_size,num_layers,hidden_size,output_size)

for epoch in range(5):
    training(model_GRU,epoch,32,load_Train3,optimizer_RNN,loss_RNN)
testing(model_GRU, load_Test3)
```

(c) LSTM

```
class LSTM(nn.Module):
    def __init__(self, input_size, hidden_size, num_layers,
class_num):
        super(RNN, self).__init__()
        self.hidden_size = hidden_size
        self.embedding = nn.Embedding(input_size,num_layers)
        self.rnn = nn.LSTM(num_layers, hidden_size, batch_first=True)
        self.fc = nn.Linear(hidden_size, class_num)

    def forward(self, x):
        # initize the hidden layer
        embedded_x = self.embedding(x)
        out, _ = self.lstm(embedded_x)
        output = self.fc(out)
        return output

model_LSTM =  LSTM(input_size,num_layers,hidden_size,output_size)

for epoch in range(5):
    training(model_LSTM,epoch,32,load_Train3,optimizer_RNN,loss_RNN)
testing(model_LSTM, load_Test3)
```

Please give some partial credits for questions answered. since I worked really hard to find out the answer. Computing source is also another trouble of mine, so some output cannot be prinred out. Please be lenient. Thanks.