NLP: Yelp Review to Rating

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Hello! In this project, we will be looking over Yelp reviews (data available here: https://www.yelp.com/dataset (https://www.yelp.com/dataset)) and utilizing ML/DL to accurately predict what the reviews star rating is based solely on text.

This project is split into the following parts

- Libraries
- EDA
- Data Cleaning
  - Stop word removal, HTML parsing, punctuation removal, etc.
  - Creation of a cleaned *and* stemmed dataset
- Model Implementation
  - Simple BOW Model Neural Network
  - LSTM
  - One vs. All LSTM Approach
- Exploring Challenges
  - Challenge 5
  - Challenge 6

Importing necessary libraries

In [68]:
```
# General Libraries
import json
import sys
import numpy as np
import pandas as pd
import seaborn as sns
import matplotlib.pyplot as plt

# NLP
import nltk
import re
from nltk.corpus import stopwords
from bs4 import BeautifulSoup
from nltk.stem import PorterStemmer


# ML/DL
import tensorflow as tf

from sklearn.preprocessing import LabelBinarizer, LabelEncoder
from sklearn.metrics import confusion_matrix
from sklearn.model_selection import train_test_split

from tensorflow import keras
from keras import Sequential
from keras.layers import Dense, Activation, Dropout, Embedding, Conv1D, MaxPooli
from keras.preprocessing.sequence import pad_sequences
from keras.preprocessing import text, sequence
from keras import utils
from keras import regularizers
```

In [54]:
```
yelp = pd.read_json("./yelp_review_training_dataset.jsonl", lines = True)
yelp.head()
```

Out[54]:

	review_id	text	stars
0	Q1sbwvVQXV2734tPgoKj4Q	Total bill for this horrible service? Over $8G...	1
1	GJXCdrto3ASJOqKeVWPi6Q	I *adore* Travis at the Hard Rock's new Kelly ...	5
2	2TzJjDVDEuAW6MR5Vuc1ug	I have to say that this office really has it t...	5
3	yi0R0Ugj_xUx_Nek0-_Qig	Went in for a lunch. Steak sandwich was delici...	5
4	11a8sVPMUFtaC7_ABRkmtw	Today was my second out of three sessions I ha...	1

How large is the data?

In [55]:
```
yelp.shape
```

Out[55]:
```
(533581, 3)
```

EDA - Stars

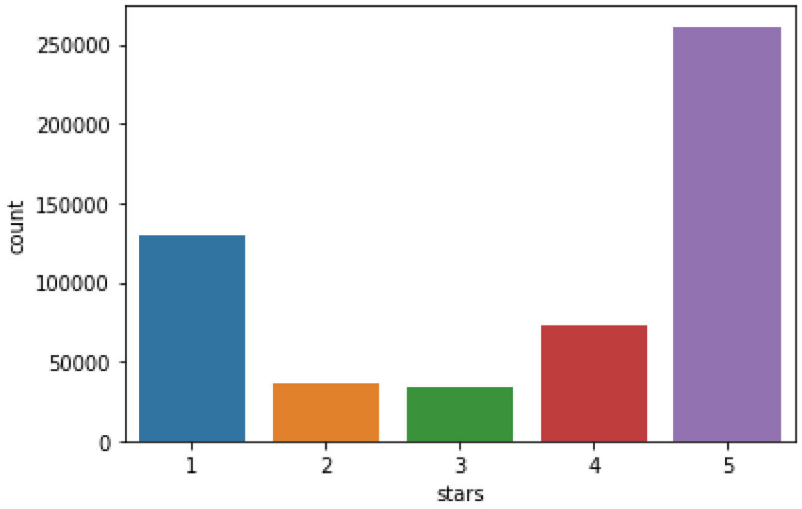
Not too much to go off of, but let's get a general understanding of our data. How many nulls do we have?

In [56]:
```
yelp.isna().sum()
```

Out[56]:
```
review_id    0
text         0
stars        0
dtype: int64
```

In [57]:
```
sns.countplot(yelp['stars'])
```

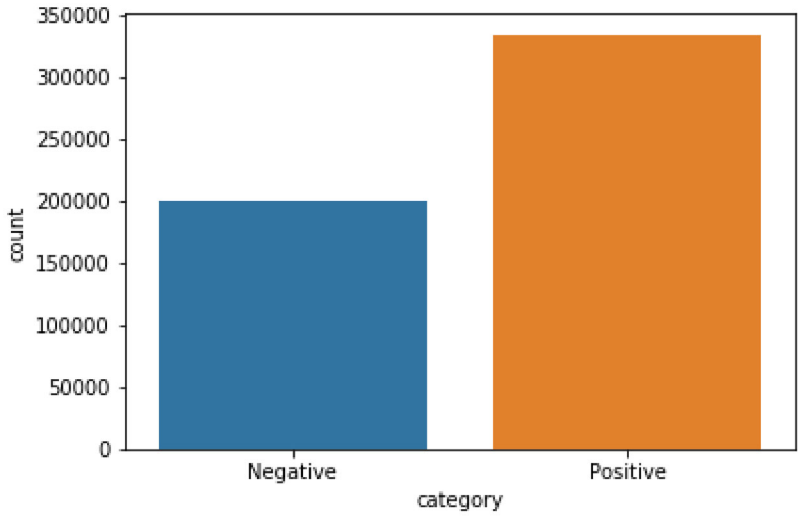
Out[57]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x223320ddf48>
```



One thing we can potentially look at is whether or not the reviews are balanced. Let's say >=4 is positive, and <4 is negative. If we do see a significant difference in positive and negative reviews, we can balance it before training.

In [58]:
```
def pos_or_neg(x):
    if x >= 4:
        return "Positive"
    else:
        return "Negative"

yelp['category'] = yelp['stars'].apply(pos_or_neg)

sns.countplot(yelp['category'])
num_pos = np.count_nonzero(yelp['category'] == 'Positive')
num_neg = np.count_nonzero(yelp['category'] == 'Negative')
print("Positive to negative review ratio: ", num_pos / num_neg)
```

```
Positive to negative review ratio:  1.6679183395916979
```



There are roughly 1 and 2/3 times as many positive reviews as negative reviews. We will first try no class balancing when building the model, but may turn to class balancing later on.

Data Cleaning - Text

In [62]:
```
REPLACE_BY_SPACE_RE = re.compile('[/(){}\[\]\|@,;]')
BAD_SYMBOLS_RE = re.compile('[^0-9a-z #+_]')
STOPWORDS = set(stopwords.words('english'))
print(STOPWORDS)

def adjust_stopwords(stopwords):
    words_to_keep = set('nor', 'not', 'very', 'no')

def clean_text(text):
    """
        text: a string

        return: modified initial string
    """
    new_text = BeautifulSoup(text, "lxml").text # HTML decoding
    new_text = new_text.lower() # lowercase text
    new_text = REPLACE_BY_SPACE_RE.sub(' ', new_text) # replace REPLACE_BY_SPACE_
    new_text = BAD_SYMBOLS_RE.sub(' ', new_text) # delete symbols which are in BA

    ps = PorterStemmer()

    new_text = ' '.join(ps.stem(word) for word in new_text.split()) # keeping al
#     new_text = ' '.join(ps.stem(word) for word in new_text.split() if word not
    return new_text
```

```
{'nor', 'against', 'm', 'not', "mightn't", 'am', 'them', 'very', 'my', 'ain',
'shouldn', 'mightn', 'be', 'having', 'this', 'those', 'down', 'that', 'i', 'doe
s', 'about', 're', "needn't", 'any', 'can', 'and', 'why', 'being', 'some', 'w
e', 'what', 'aren', 'didn', 'most', 'have', 'haven', 'himself', 'ma', 'after',
'is', 'do', 'by', 'up', 'just', 'each', 'shan', 'don', 'doesn', 'out', "she's",
'below', 'on', 'where', 'its', 'wouldn', 'did', 'then', 'yours', 'won', 'of',
'at', 'been', 'herself', 'they', 'over', 'in', 'who', "it's", "haven't", 'whic
h', 'you', 'until', 'under', "doesn't", "won't", 'now', 'but', 'all', 'than',
"you're", 'he', 'above', 'will', 'to', 'couldn', "hadn't", 'our', "you've", 'wh
om', 'before', 'few', 't', 'ourselves', "shouldn't", 'or', 'so', 'd', 'it', 'my
self', 'the', 'his', 'hasn', 'more', 'during', "you'll", "wasn't", 'wasn', 'sam
e', 'a', 'doing', 'her', "shan't", 'weren', 'yourself', 'should', 'was', "would
n't", 'too', 'ours', 'has', 'while', 'for', 'had', 'itself', 'yourselves', "yo
u'd", 'are', 'off', 'an', "aren't", 'were', 'as', 'your', 'll', 'with', 'themse
lves', 'hers', 'because', 'again', 'she', "don't", 'from', 'through', 'isn', 't
heirs', 'both', "hasn't", 'such', 'into', "couldn't", "weren't", 'mustn', 'ho
w', "isn't", 'me', 'him', "mustn't", 'hadn', "that'll", 'their', 'no', 'other',
'these', "didn't", 'between', 'if', 've', 'y', "should've", 'when', 'needn', 'o
nly', 'further', 'own', 'there', 'o', 's', 'once', 'here'}
```

```
C:\Users\Tanner\Anaconda3\lib\site-packages\bs4\__init__.py:357: UserWarning:
"https://www.consumeraffairs.com/news/mypillow-gets-a-rude-awakening-as-the-b
etter-business-bureau-gives-it-an-f-010517.html" looks like a URL. Beautiful
Soup is not an HTTP client. You should probably use an HTTP client like reque
sts to get the document behind the URL, and feed that document to Beautiful S
oup.
  ' that document to Beautiful Soup.' % decoded_markup
C:\Users\Tanner\Anaconda3\lib\site-packages\bs4\__init__.py:294: UserWarning:
```

```
"b'.'" looks like a filename, not markup. You should probably open this file
and pass the filehandle into Beautiful Soup.
  ' Beautiful Soup.' % markup)
C:\Users\Tanner\Anaconda3\lib\site-packages\bs4\__init__.py:357: UserWarning:
"http://www.marketwired.com/press-release/lease-of-spot-concord-place-cafe-te
rminated-tsx-venture-spp-1950108.htm

Unfortunate!" looks like a URL. Beautiful Soup is not an HTTP client. You sho
uld probably use an HTTP client like requests to get the document behind the
URL, and feed that document to Beautiful Soup.
  ' that document to Beautiful Soup.' % decoded_markup
C:\Users\Tanner\Anaconda3\lib\site-packages\bs4\__init__.py:294: UserWarning:
"b'...'" looks like a filename, not markup. You should probably open this fil
e and pass the filehandle into Beautiful Soup.
  ' Beautiful Soup.' % markup)
```

In [ ]:
```
yelp['text'] = yelp['text'].apply(clean_text)
yelp.to_csv('cleaned_yelp_stemmed.csv')
```

In [63]:
```
text_1 = "\"Good morning, cocktails for you?\" \nWait...what? Oh...it's Vegas!\n
text_2 = "80 bucks, thirty minutes to fix my shattered iPhone screen. Verizon wo
text_3 = "Tr\u00e8s grand caf\u00e9, mais aussi calme et reposant, je m'y suis a
text_4 = "Sadly, as of July 28, 2016, Silverstein bakery is permanently closed. 
text_5 = "I went here  they were about to close but the cashier was especially h

clean_text(text_1)
```

Out[63]:
```
'good morn cocktail for you wait what oh it s vega dine here you best not be di
et becaus thi place is liter the definit of excess but in a good way i m a suck
er for benedict so that wa awesom servic wa realli great too and the staff wa s
o welcom it wa our first stop just after land so realli appreci the servic back
in hawaii thi remind me of zippi or anna miller that home feel price are a bit
high but for what you get it s total worth it will rememb thi place if i ever r
eturn to vega in the futur'
```

Model Implementation

Evaluation

1. Average Star Error (Average Absolute offset between predicted and true number of stars)

2. Accuracy (Exact Match -- Number of exactly predicted star ratings / total samples)

In [64]:
```
def MAE(y_true, y_pred):
    diffs = np.abs(y_true - y_pred)
    loss = np.mean(diffs)
    return loss

def Accuracy(y_true, y_pred):
    correct = y_true == y_pred
    cor_count = np.count_nonzero(correct)
    return cor_count / len(y_true)
```

Train/Test Split (Unbalanced and balanced)

In [65]:
```
yelp = pd.read_csv('cleaned_yelp_stemmed.csv')
yelp.head()
```

Out[65]:

	Unnamed: 0	review_id	text	stars	category
0	0	Q1sbwvVQXV2734tPgoKj4Q	total bill for thi horribl servic over 8g thes...	1	Negative
1	1	GJXCdrto3ASJOqKeVWPi6Q	i ador travi at the hard rock s new kelli card...	5	Positive
2	2	2TzJjDVDEuAW6MR5Vuc1ug	i have to say that thi offic realli ha it toge...	5	Positive
3	3	yi0R0Ugj_xUx_Nek0-_Qig	went in for a lunch steak sandwich wa delici a...	5	Positive
4	4	11a8sVPMUFtaC7_ABRkmtw	today wa my second out of three session i had ...	1	Negative

In [66]:
```
X = yelp['text'].fillna('').values
y = yelp['stars']

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.30, random_
```

Baseline Sequential Model

In [69]:
```
max_words = 3000
tokenizer = text.Tokenizer(num_words=max_words, char_level=False)

tokenizer.fit_on_texts(X_train)
X_train = tokenizer.texts_to_matrix(X_train)
X_test = tokenizer.texts_to_matrix(X_test)

encoder = LabelEncoder()
encoder.fit(y_train)
y_train = encoder.transform(y_train)
y_test = encoder.transform(y_test)

num_classes = np.max(y_train) + 1
y_train = utils.to_categorical(y_train, num_classes)
y_test = utils.to_categorical(y_test, num_classes)

print('X_train shape:', X_train.shape)
print('X_test shape:', X_test.shape)
print('y_train shape:', y_train.shape)
print('y_test shape:', y_test.shape)
```

```
X_train shape: (373506, 3000)
X_test shape: (160075, 3000)
y_train shape: (373506, 5)
y_test shape: (160075, 5)
```

Let's save the tokenizer as well for our test submission file script.

In [70]:
```
import pickle

# saving
with open('tokenizer.pickle', 'wb') as handle:
    pickle.dump(tokenizer, handle, protocol=pickle.HIGHEST_PROTOCOL)

# loading
with open('tokenizer.pickle', 'rb') as handle:
    tokenizer = pickle.load(handle)
```

Here, we are computing a single model, but in future we will optimize on several parameters, listed below

- Batch size
- Learning rate
- Gradient clipping
- Drop out
- Batch normalization
- Optimizers
- Regularization

After some tests, the main variations I noticed were from the learning rate, regularization, and the choice of the optimizer. With that being said, this baseline model will use **ADAM with a learning rate of .0001 and regularization (kernel, bias, and activity)**

In [74]:
```
batch_size = 512
epochs = 10

lr_schedule = keras.optimizers.schedules.ExponentialDecay(
    initial_learning_rate=.0001,
    decay_steps=10000,
    decay_rate=0.9)

optimizer = keras.optimizers.Adam(learning_rate=lr_schedule, beta_1=0.9, beta_2=(

model = Sequential()
model.add(Dense(512, input_shape=(max_words,), kernel_regularizer=regularizers.l1
          bias_regularizer=regularizers.l2(1e-4),
          activity_regularizer=regularizers.l2(1e-5)))
model.add(BatchNormalization())
model.add(Activation('relu'))
model.add(Dropout(0.3))
model.add(Dense(5))
model.add(Activation('softmax'))

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

history = model.fit(X_train, y_train,
                    batch_size=batch_size,
                    epochs=epochs,
                    verbose=1,
                    validation_split=0.2)
```

```
Train on 298804 samples, validate on 74702 samples
Epoch 1/10
298804/298804 [==============================] - 38s 128us/step - loss: 1.299
7 - accuracy: 0.6899 - val_loss: 1.0994 - val_accuracy: 0.7449
Epoch 2/10
298804/298804 [==============================] - 16s 53us/step - loss: 1.0668
- accuracy: 0.7480 - val_loss: 1.0303 - val_accuracy: 0.7500
Epoch 3/10
298804/298804 [==============================] - 11s 37us/step - loss: 0.9758
- accuracy: 0.7628 - val_loss: 0.9810 - val_accuracy: 0.7524
Epoch 4/10
298804/298804 [==============================] - 11s 37us/step - loss: 0.9052
- accuracy: 0.7747 - val_loss: 0.9418 - val_accuracy: 0.7528
Epoch 5/10
298804/298804 [==============================] - 11s 38us/step - loss: 0.8479
- accuracy: 0.7826 - val_loss: 0.9077 - val_accuracy: 0.7523
Epoch 6/10
298804/298804 [==============================] - 11s 37us/step - loss: 0.8001
- accuracy: 0.7910 - val_loss: 0.8838 - val_accuracy: 0.7531
Epoch 7/10
298804/298804 [==============================] - 11s 38us/step - loss: 0.7581
- accuracy: 0.8000 - val_loss: 0.8665 - val_accuracy: 0.7518
Epoch 8/10
298804/298804 [==============================] - 11s 38us/step - loss: 0.7221
- accuracy: 0.8080 - val_loss: 0.8523 - val_accuracy: 0.7528
Epoch 9/10
```

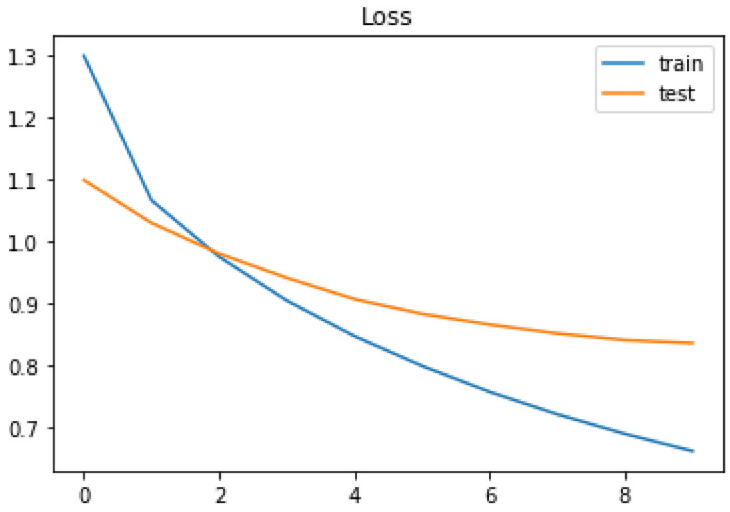
```
298804/298804 [==============================] - 11s 37us/step - loss: 0.6905
- accuracy: 0.8157 - val_loss: 0.8416 - val_accuracy: 0.7515
Epoch 10/10
298804/298804 [==============================] - 11s 38us/step - loss: 0.6629
- accuracy: 0.8225 - val_loss: 0.8368 - val_accuracy: 0.7514
```

In [75]:
```
score = model.evaluate(X_test, y_test,
                       batch_size=batch_size, verbose=1)
print('Test accuracy:', score[1])
```

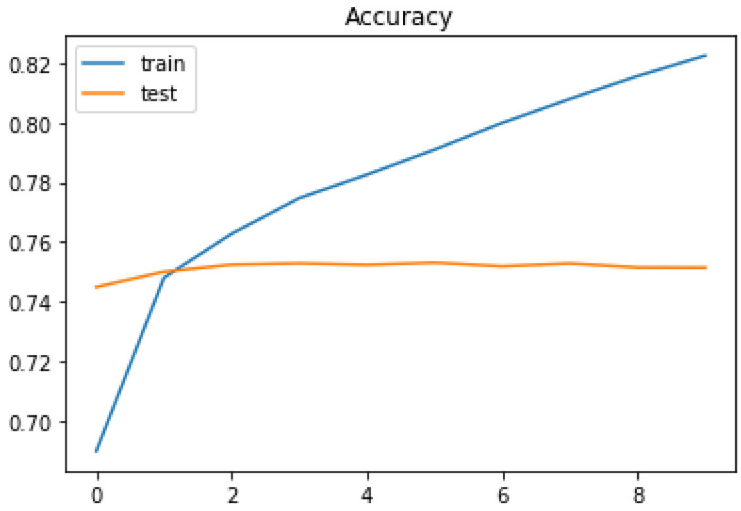
```
160075/160075 [==============================] - 13s 84us/step
Test accuracy: 0.7534281015396118
```

In [ ]:
```
train_predictions = model.predict(X_train)
test_predictions = model.predict(X_test)
```

In [76]:
```
plt.title('Loss')
plt.plot(history.history['loss'], label='train')
plt.plot(history.history['val_loss'], label='test')
plt.legend()
plt.show()
```



In [77]:
```
plt.title('Accuracy')
plt.plot(history.history['accuracy'], label='train')
plt.plot(history.history['val_accuracy'], label='test')
plt.legend()
plt.show()
```



In [85]:
```
model.save('./models/baseline.h5')
```

Now training with several parameter changes

In [ ]:
```
import itertools

batch_sizes = [128, 256, 512]
epochs = [5]
learning_rates = [.01, .001, .0001]
dropout = [False, True]
batch_norm = [False, True]
regularization = [True]
optimizers = ["SGD", "RMSProp", "ADAM"]

all_lists = [batch_sizes, epochs, learning_rates, dropout, batch_norm, regulariz

params_to_test = list(itertools.product(*all_lists))
print(len(params_to_test))
```

In [ ]:
```
models = {}
histories = {}
scores = {}

for params in params_to_test:
    print(params)
    batch_size, epochs, learning_rate, dropout, batch_norm, regularization, opt =

    if opt == "SGD":
        optimizer = keras.optimizers.SGD(learning_rate=learning_rate, momentum=0
    elif opt == "RMSProp":
        optimizer = keras.optimizers.RMSprop(learning_rate=learning_rate, rho=0.
    elif opt == "ADAM":
        optimizer = keras.optimizers.Adam(learning_rate=learning_rate, beta_1=0.
    else:
        optimizer = keras.optimizers.Adadelta(learning_rate=learning_rate, rho=0

    model = Sequential()
    model.add(Dense(512, input_shape=(max_words,), kernel_regularizer=regularize

    # Check Batch Normalization
    if batch_norm:
        model.add(BatchNormalization())

    model.add(Activation('relu'))

    # Check Dropout
    if dropout:
        model.add(Dropout(0.2))

    model.add(Dense(5))
    model.add(Activation('softmax'))

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

    history = model.fit(X_train, y_train,
                        batch_size=batch_size,
                        epochs=epochs,
                        verbose=0,
                        validation_split=0.1)

    models[params] = model
    histories[params] = history

    score = model.evaluate(X_test, y_test, batch_size=batch_size, verbose=1)
    print(score)

    scores[params] = score
```

LSTM Model

Specific Data Prep

In [78]:
```
from sklearn.model_selection import train_test_split

X = yelp['text'].fillna('').values
y = pd.get_dummies(yelp['stars']).values

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.3, random_
print(X_train.shape, y_train.shape)
print(X_test.shape, y_test.shape)

max_words = 3000
maxlen = 400

X_train = tokenizer.texts_to_sequences(X_train)
X_test = tokenizer.texts_to_sequences(X_test)

# For the LSTM, we are going to pad our sequences
X_train = pad_sequences(X_train, maxlen=maxlen)
X_test = pad_sequences(X_test, maxlen=maxlen)
```

```
(373506,) (373506, 5)
(160075,) (160075, 5)
```

LSTM #1

In [79]:
```
batch_size = 512
epochs = 10

lr_schedule = keras.optimizers.schedules.ExponentialDecay(
    initial_learning_rate=.001,
    decay_steps=10000,
    decay_rate=0.9)

optimizer = keras.optimizers.Adam(learning_rate=lr_schedule, beta_1=0.9, beta_2=(

lstm = Sequential()
lstm.add(Embedding(max_words, 128, input_length=maxlen))
lstm.add(SpatialDropout1D(0.2))
lstm.add(Conv1D(64, 5, activation='relu', kernel_regularizer=regularizers.l1_l2(
          bias_regularizer=regularizers.l2(1e-4)))
lstm.add(MaxPooling1D(pool_size=4))
lstm.add(LSTM(128, dropout=0.2, recurrent_dropout=0.2))
lstm.add(BatchNormalization())
lstm.add(Dense(5, activation='sigmoid'))

lstm.compile(loss='categorical_crossentropy',
             optimizer=optimizer,
             metrics=['accuracy'])

history = lstm.fit(X_train, y_train,
                   batch_size=batch_size,
                   epochs=epochs,
                   verbose=1,
                   validation_split=0.2)
```

```
Train on 298804 samples, validate on 74702 samples
Epoch 1/10
298804/298804 [==============================] - 87s 290us/step - loss: 0.784
0 - accuracy: 0.7080 - val_loss: 0.6677 - val_accuracy: 0.7473
Epoch 2/10
298804/298804 [==============================] - 82s 275us/step - loss: 0.648
2 - accuracy: 0.7529 - val_loss: 0.6177 - val_accuracy: 0.7638
Epoch 3/10
298804/298804 [==============================] - 82s 273us/step - loss: 0.608
9 - accuracy: 0.7650 - val_loss: 0.5955 - val_accuracy: 0.7715
Epoch 4/10
298804/298804 [==============================] - 84s 280us/step - loss: 0.586
2 - accuracy: 0.7724 - val_loss: 0.5892 - val_accuracy: 0.7726
Epoch 5/10
298804/298804 [==============================] - 83s 279us/step - loss: 0.572
2 - accuracy: 0.7775 - val_loss: 0.5826 - val_accuracy: 0.7754
Epoch 6/10
298804/298804 [==============================] - 86s 288us/step - loss: 0.557
5 - accuracy: 0.7835 - val_loss: 0.5828 - val_accuracy: 0.7750
Epoch 7/10
298804/298804 [==============================] - 87s 290us/step - loss: 0.548
5 - accuracy: 0.7868 - val_loss: 0.5810 - val_accuracy: 0.7787
Epoch 8/10
298804/298804 [==============================] - 88s 293us/step - loss: 0.539
5 - accuracy: 0.7905 - val_loss: 0.5791 - val_accuracy: 0.7791
Epoch 9/10
298804/298804 [==============================] - 86s 289us/step - loss: 0.530
```

```
8 - accuracy: 0.7942 - val_loss: 0.5943 - val_accuracy: 0.7749
Epoch 10/10
298804/298804 [==============================] - 86s 287us/step - loss: 0.521
1 - accuracy: 0.7983 - val_loss: 0.5816 - val_accuracy: 0.7798
```

LSTM #1: Evaluation

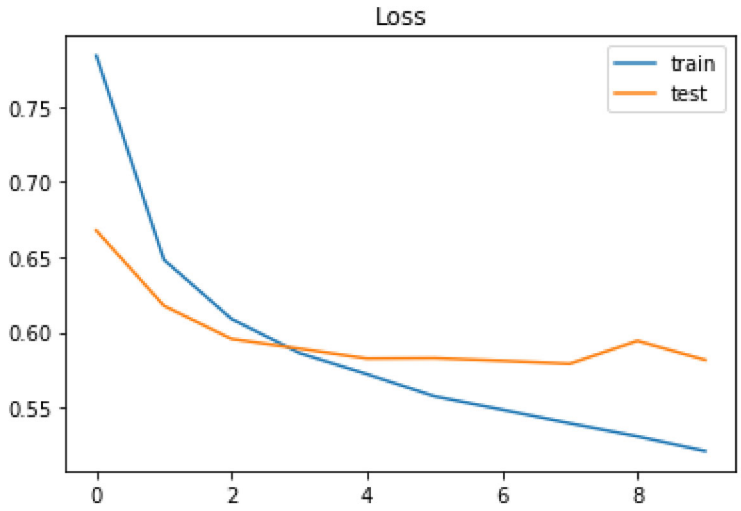
In [80]:
```
score = lstm.evaluate(X_test, y_test,
                      batch_size=batch_size, verbose=1)
print('Test accuracy:', score[1])
```

```
160075/160075 [==============================] - 11s 68us/step
Test accuracy: 0.7814836502075195
```

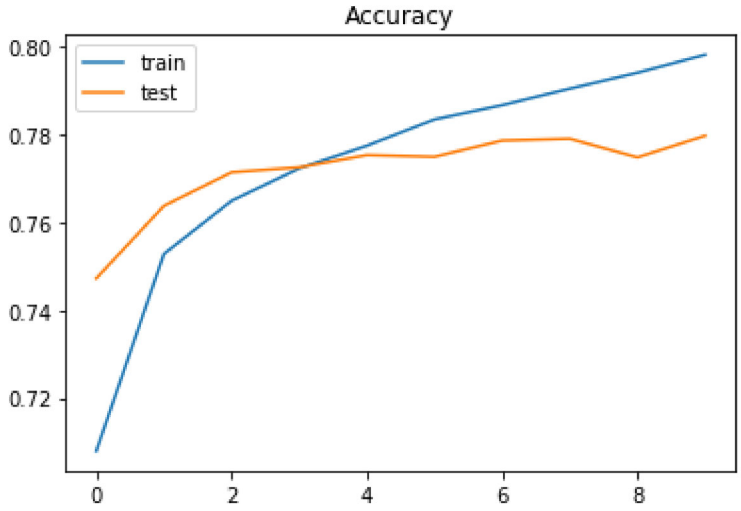
In [81]:
```
lstm.summary()
```

```
Model: "sequential_3"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
embedding_1 (Embedding)      (None, 400, 128)          384000
_________________________________________________________________
spatial_dropout1d_1 (Spatial (None, 400, 128)          0
_________________________________________________________________
conv1d_1 (Conv1D)            (None, 396, 64)           41024
_________________________________________________________________
max_pooling1d_1 (MaxPooling1 (None, 99, 64)            0
_________________________________________________________________
lstm_1 (LSTM)                (None, 128)               98816
_________________________________________________________________
batch_normalization_3 (Batch (None, 128)               512
_________________________________________________________________
dense_5 (Dense)              (None, 5)                 645
=================================================================
Total params: 524,997
Trainable params: 524,741
Non-trainable params: 256
_________________________________________________________________
```

In [82]:
```
plt.title('Loss')
plt.plot(history.history['loss'], label='train')
plt.plot(history.history['val_loss'], label='test')
plt.legend()
plt.show()
```



In [83]:
```
plt.title('Accuracy')
plt.plot(history.history['accuracy'], label='train')
plt.plot(history.history['val_accuracy'], label='test')
plt.legend()
plt.show()
```



Let's save this model as well.

In [84]:
```
lstm.save('./models/lstm.h5')
```

```
C:\Users\Tanner\Anaconda3\lib\site-packages\keras\engine\saving.py:165: UserWar
ning: TensorFlow optimizers do not make it possible to access optimizer attribu
tes or optimizer state after instantiation. As a result, we cannot save the opt
imizer as part of the model save file.You will have to compile your model again
after loading it. Prefer using a Keras optimizer instead (see keras.io/optimize
rs).
  'TensorFlow optimizers do not '
```

One vs. All Approach

In the one vs. all approach, it goes by the following idea:

- We will have N learners for the multi-class classification problem, where N is the number of classes
- For each learner L, we will train L on our training data X_{Train} and y_{Train}. However, y_{Train} consists of only one label, making it a binary classification problem instead of multinomial
  - For instance, learner L_1 will still use all of X_{Train}, but y_{Train} will now be transformed to be a binary vector v_i where i denotes the star rating we are attempting to predict
- Once we have concluded our training, we will then create an ensemble model (bagging) that does the following
  1. L_1, L_2, ..., L_5 all assign p_i to each record in X_{Test}, where p_i is the likelihood observation x_n belongs to class i
  2. From there, our prediction is the following: $P_n = argmax(p_1, p_2, p_3, p_4, p_5)$

After observing the challenge datasets 5 & 6, my partner and I believe this approach is a clever way to tackle the challenges while still having a strong model.

Sources: [https://developers.google.com/machine-learning/crash-course/multi-class-neural-networks/one-vs-all (https://developers.google.com/machine-learning/crash-course/multi-class-neural-networks/one-vs-all)](https://developers.google.com/machine-learning/crash-course/multi-class-neural-networks/one-vs-all)

In [86]:
```
yelp = pd.read_csv('cleaned_yelp_stemmed.csv')

X = yelp['text'].fillna('').values
y = pd.get_dummies(yelp['stars']).values

X_train, X_test, y_train, y_test = train_test_split(X, y, test_size=0.30, random_

max_words = 3000
maxlen = 400

X_train = tokenizer.texts_to_sequences(X_train)
X_test = tokenizer.texts_to_sequences(X_test)
X_train = pad_sequences(X_train, maxlen=maxlen)
X_test = pad_sequences(X_test, maxlen=maxlen)

print('X_train shape:', X_train.shape)
print('X_test shape:', X_test.shape)
print('y_train shape:', y_train.shape)
print('y_test shape:', y_test.shape)
```

```
X_train shape: (373506, 400)
X_test shape: (160075, 400)
y_train shape: (373506, 5)
y_test shape: (160075, 5)
```

Buidling all models

In [87]:
```
stars = np.arange(1, 6)
models = {}
histories = {}
batch_size = 1024
epochs = 3

for star in stars:
    print(star)
    y_train_sub = y_train[:, star - 1]

    lr_schedule = keras.optimizers.schedules.ExponentialDecay(
    initial_learning_rate=.001,
    decay_steps=10000,
    decay_rate=0.9)

    optimizer = keras.optimizers.Adam(learning_rate=lr_schedule, beta_1=0.9, beta

    sub_lstm = Sequential()
    sub_lstm.add(Embedding(max_words, 128, input_length=maxlen))
    sub_lstm.add(SpatialDropout1D(0.2))
    sub_lstm.add(Conv1D(64, 5, activation='relu', kernel_regularizer=regularizers
              bias_regularizer=regularizers.l2(1e-4)))
    sub_lstm.add(MaxPooling1D(pool_size=4))
    sub_lstm.add(LSTM(128))
    sub_lstm.add(BatchNormalization())
    sub_lstm.add(Dense(8))
    sub_lstm.add(Dense(1, activation='sigmoid'))

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

    history = sub_lstm.fit(X_train, y_train_sub,
                        batch_size=batch_size,
                        epochs=epochs,
                        verbose=1,
                        validation_split=0.2)

    models[star] = sub_lstm
    histories[star] = sub_lstm
```

```
1
Train on 298804 samples, validate on 74702 samples
Epoch 1/3
298804/298804 [==============================] - 66s 222us/step - loss: 0.2552
- accuracy: 0.9035 - val_loss: 0.6392 - val_accuracy: 0.7587
Epoch 2/3
298804/298804 [==============================] - 65s 216us/step - loss: 0.1803
- accuracy: 0.9329 - val_loss: 0.4301 - val_accuracy: 0.8117
Epoch 3/3
298804/298804 [==============================] - 63s 212us/step - loss: 0.1563
- accuracy: 0.9421 - val_loss: 0.2291 - val_accuracy: 0.9059
2
Train on 298804 samples, validate on 74702 samples
Epoch 1/3
298804/298804 [==============================] - 65s 216us/step - loss: 0.2544
```

```
- accuracy: 0.9196 - val_loss: 0.2822 - val_accuracy: 0.9323
Epoch 2/3
298804/298804 [==============================] - 64s 213us/step - loss: 0.1831
- accuracy: 0.9354 - val_loss: 0.2181 - val_accuracy: 0.9325
Epoch 3/3
298804/298804 [==============================] - 63s 211us/step - loss: 0.1636
- accuracy: 0.9406 - val_loss: 0.2006 - val_accuracy: 0.9282
3
Train on 298804 samples, validate on 74702 samples
Epoch 1/3
298804/298804 [==============================] - 64s 216us/step - loss: 0.2517
- accuracy: 0.9216 - val_loss: 0.2613 - val_accuracy: 0.9363
Epoch 2/3
298804/298804 [==============================] - 64s 215us/step - loss: 0.1765
- accuracy: 0.9389 - val_loss: 0.2136 - val_accuracy: 0.9364
Epoch 3/3
298804/298804 [==============================] - 64s 213us/step - loss: 0.1586
- accuracy: 0.9437 - val_loss: 0.2292 - val_accuracy: 0.9376
4
Train on 298804 samples, validate on 74702 samples
Epoch 1/3
298804/298804 [==============================] - 64s 216us/step - loss: 0.3626
- accuracy: 0.8537 - val_loss: 0.4075 - val_accuracy: 0.8639
Epoch 2/3
298804/298804 [==============================] - 64s 214us/step - loss: 0.3048
- accuracy: 0.8741 - val_loss: 0.3576 - val_accuracy: 0.8644
Epoch 3/3
298804/298804 [==============================] - 64s 215us/step - loss: 0.2837
- accuracy: 0.8828 - val_loss: 0.3255 - val_accuracy: 0.8629
5
Train on 298804 samples, validate on 74702 samples
Epoch 1/3
298804/298804 [==============================] - 68s 228us/step - loss: 0.3479
- accuracy: 0.8600 - val_loss: 0.4756 - val_accuracy: 0.8689
Epoch 2/3
298804/298804 [==============================] - 66s 220us/step - loss: 0.2878
- accuracy: 0.8858 - val_loss: 0.3429 - val_accuracy: 0.8524
Epoch 3/3
298804/298804 [==============================] - 65s 217us/step - loss: 0.2607
- accuracy: 0.8963 - val_loss: 0.2899 - val_accuracy: 0.8817
```

Building an ensemble model (maximization between learners) for all trained models

Testing

In [88]:
```
# Evaluating the models above (TEST)
y_test_und = pd.DataFrame(y_test)
y_test_true = pd.DataFrame(y_test_und.columns[np.where(y_test_und!=0)[1]]) + 1

# Unload models
lstm_1, lstm_2, lstm_3, lstm_4, lstm_5 = models[1], models[2], models[3], models

## Predicting the probability for each observation each model
print("Predicting 1 star")
one_star_ps = lstm_1.predict(X_test)
print("Predicting 2 star")
two_star_ps = lstm_2.predict(X_test)
print("Predicting 3 star")
three_star_ps = lstm_3.predict(X_test)
print("Predicting 4 star")
four_star_ps = lstm_4.predict(X_test)
print("Predicting 5 star")
five_star_ps = lstm_5.predict(X_test)

data = [one_star_ps.flatten(), two_star_ps.flatten(), three_star_ps.flatten(), f
cols = [1, 2, 3, 4, 5]
ps = pd.DataFrame(data=data, index=cols).T

ps["pred"] = ps.idxmax(axis=1)
ps.head()

print(MAE(ps["pred"], y_test_true[0]))
print(Accuracy(ps["pred"], y_test_true[0]))
```

```
0.3283898172731532
0.755470873028268
```

Saving the models

In [89]:
```
from keras.models import load_model

lstm_1.save("one_star.h5")
lstm_2.save("two_star.h5")
lstm_3.save("three_star.h5")
lstm_4.save("four_star.h5")
lstm_5.save("five_star.h5")
```

```
C:\Users\Tanner\Anaconda3\lib\site-packages\keras\engine\saving.py:165: UserWar
ning: TensorFlow optimizers do not make it possible to access optimizer attribu
tes or optimizer state after instantiation. As a result, we cannot save the opt
imizer as part of the model save file.You will have to compile your model again
after loading it. Prefer using a Keras optimizer instead (see keras.io/optimize
rs).
  'TensorFlow optimizers do not '
```

Challenges

Challenge 5

In [90]:
```
c5 = pd.read_json("./yelp_challenge_5_with_answers.jsonl", lines = True)
print(c5.shape)
c5.head()
```

```
(500, 3)
```

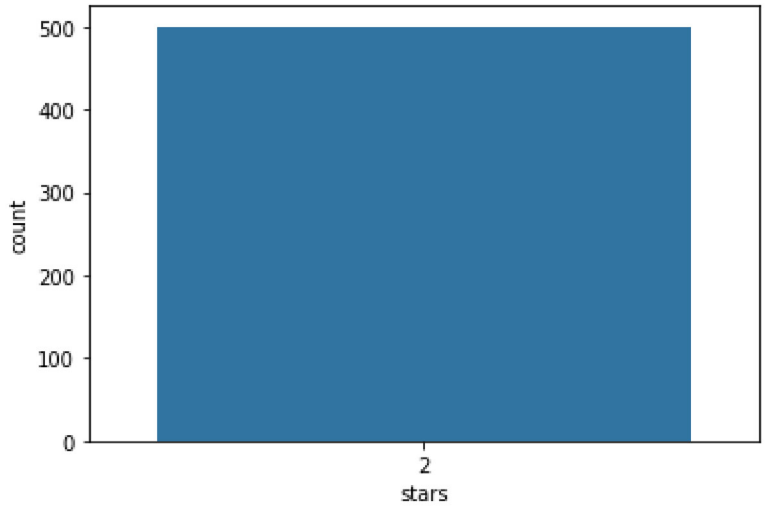
Out[90]:

	review_id	text	stars
0	50	I went to this campus for 1 semester. I was in...	2
1	51	I have rated it a two star based on its compar...	2
2	52	Just like most of the reviews, we ordered and ...	2
3	53	I only go here if it is an emergency. I HATE i...	2
4	54	Rude staff. I got 60 feeder fish and about 15 ...	2

Quick EDA

In [91]:
```
sns.countplot(c5['stars'])
```

Out[91]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x2260ee05088>
```



Pre-processing

In [92]:
```
c5['text'] = c5['text'].apply(clean_text)
c5.head()
```

Out[92]:

	review_id	text	stars
0	50	i went to thi campu for 1 semest i wa in busi ...	2
1	51	i have rate it a two star base on it compariso...	2
2	52	just like most of the review we order and paid...	2
3	53	i onli go here if it is an emerg i hate it tha...	2
4	54	rude staff i got 60 feeder fish and about 15 w...	2

Load previous tokenizer

In [93]:
```
X = c5['text'].fillna('').values
y = pd.get_dummies(c5['stars'])

with open('tokenizer.pickle', 'rb') as handle:
    tokenizer = pickle.load(handle)

max_words

necc_cols = [1, 2, 3, 4, 5]
for col in necc_cols:
    if col not in y.columns:
        y[col] = 0

y = y[necc_cols]
y = y.values

X_baseline = tokenizer.texts_to_matrix(X)
X_lstm = tokenizer.texts_to_sequences(X)
X_lstm = pad_sequences(X_lstm, maxlen=400)
```

Load and compile models

In [94]:
```
# Baseline
baseline = load_model('./models/baseline.h5')

baseline.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# LSTM
lstm = load_model('./models/lstm.h5')

lstm.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])


# One vs. all
lstm_1 = load_model('./models/one_star.h5')

lstm_1.compile(loss='binary_crossentropy',
                  optimizer=optimizer,
                  metrics=['accuracy'])

lstm_2 = load_model('./models/two_star.h5')

lstm_2.compile(loss='binary_crossentropy',
                  optimizer=optimizer,
                  metrics=['accuracy'])

lstm_3 = load_model('./models/three_star.h5')

lstm_3.compile(loss='binary_crossentropy',
                  optimizer=optimizer,
                  metrics=['accuracy'])

lstm_4 = load_model('./models/four_star.h5')

lstm_4.compile(loss='binary_crossentropy',
                  optimizer=optimizer,
                  metrics=['accuracy'])

lstm_5 = load_model('./models/five_star.h5')

lstm_5.compile(loss='binary_crossentropy',
                  optimizer=optimizer,
                  metrics=['accuracy'])
```

```
C:\Users\Tanner\Anaconda3\lib\site-packages\keras\engine\saving.py:341: UserWar
ning: No training configuration found in save file: the model was *not* compile
d. Compile it manually.
  warnings.warn('No training configuration found in save file: '
```

Evaluate Models

In [95]:
```
# Baseline
print(baseline.evaluate(X_baseline, y))

# LSTM
print(lstm.evaluate(X_lstm, y))

# One vs. All
one_star_ps = lstm_1.predict(X_lstm)
two_star_ps = lstm_2.predict(X_lstm)
three_star_ps = lstm_3.predict(X_lstm)
four_star_ps = lstm_4.predict(X_lstm)
five_star_ps = lstm_5.predict(X_lstm)

data = [one_star_ps.flatten(), two_star_ps.flatten(), three_star_ps.flatten(), f
cols = [1, 2, 3, 4, 5]
ps = pd.DataFrame(data=data, index=cols).T

ps["ova_pred"] = ps.idxmax(axis=1)

print([MAE(ps["ova_pred"], pd.DataFrame(data=y, columns=cols).idxmax(axis=1)), A
```

```
500/500 [==============================] - 0s 160us/step
[1.984132592201233, 0.2980000078678131]
500/500 [==============================] - 0s 720us/step
[1.4631506433486938, 0.35600000619888306]
[2.29, 0.136]
```

Attempt Ensemble

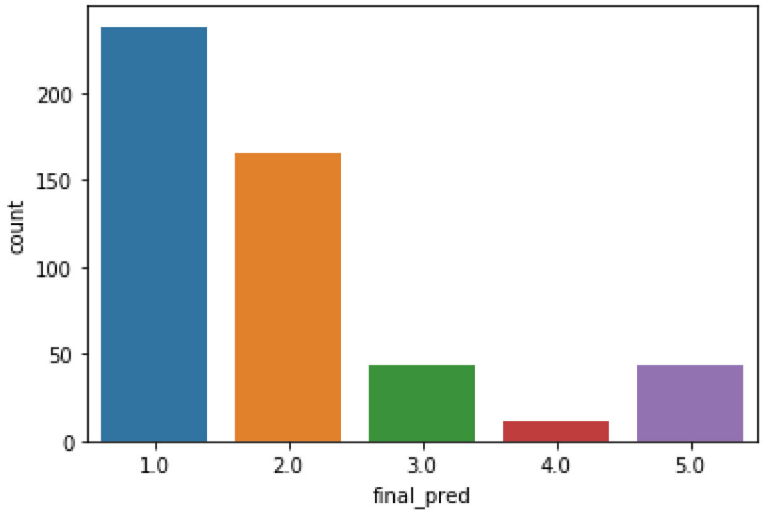
In [96]:
```
# Baseline
baseline_preds = pd.DataFrame(baseline.predict(X_baseline), columns=cols)
baseline_preds['baseline_pred'] = baseline_preds.idxmax(axis=1)

# LSTM
lstm_preds = pd.DataFrame(lstm.predict(X_lstm), columns=cols)
lstm_preds['lstm_pred'] = lstm_preds.idxmax(axis=1)

# One vs. all
ova_preds = ps

all_preds = pd.DataFrame([baseline_preds['baseline_pred'], lstm_preds['lstm_pred
all_preds["final_pred"] = all_preds.mode(axis=1)[0]

print([MAE(all_preds["final_pred"], pd.DataFrame(data=y, columns=cols).idxmax(ax
```

```
[0.864, 0.33]
```

Misc.

In [97]:
```
sns.countplot(all_preds["final_pred"])
```

Out[97]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x2239db3aa88>
```



Challenge 6

In [98]:
```
c6 = pd.read_json("./yelp_challenge_6_with_answers.jsonl", lines = True)
print(c6.shape)
c6.head()
```

```
(500, 3)
```

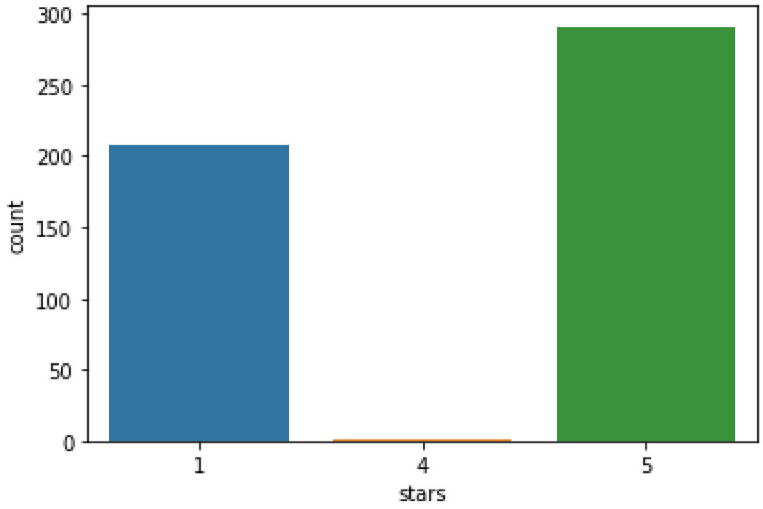
Out[98]:

	review_id	text	stars
0	60	Amazing for Trees\n\n$20 for a 5 gallon . I wi...	5
1	61	How the hell can Taco Bell be closed before mi...	5
2	62	I actually had no intention of visiting this p...	5
3	63	Yesterday around 3:30 pm I was driving west on...	5
4	64	DR FITZMAURICE did surgery on both hands on th...	5

Quick EDA

In [99]:
```
sns.countplot(c6['stars'])
```

Out[99]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x22396a47388>
```



Pre-processing

In [100]:
```
c6['text'] = c6['text'].apply(clean_text)
c6.head()
```

Out[100]:

	review_id	text	stars
0	60	amaz for tree 20 for a 5 gallon i will never g...	5
1	61	how the hell can taco bell be close befor midn...	5
2	62	i actual had no intent of visit thi place at a...	5
3	63	yesterday around 3 30 pm i wa drive west on pi...	5
4	64	dr fitzmauric did surgeri on both hand on the ...	5

Load previous tokenizer

In [101]:
```
X = c6['text'].fillna('').values
y = pd.get_dummies(c6['stars'])

with open('tokenizer.pickle', 'rb') as handle:
    tokenizer = pickle.load(handle)

max_words

necc_cols = [1, 2, 3, 4, 5]
for col in necc_cols:
    if col not in y.columns:
        y[col] = 0

y = y[necc_cols]
y = y.values

X_baseline = tokenizer.texts_to_matrix(X)
X_lstm = tokenizer.texts_to_sequences(X)
X_lstm = pad_sequences(X_lstm, maxlen=400)
```

Load and compile models

In [102]:
```
from keras.models import load_model

# Baseline
baseline = load_model('./models/baseline.h5')

baseline.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])

# LSTM
lstm = load_model('./models/lstm.h5')

lstm.compile(loss='categorical_crossentropy',
              optimizer=optimizer,
              metrics=['accuracy'])


# One vs. all
lstm_1 = load_model('./models/one_star.h5')

lstm_1.compile(loss='binary_crossentropy',
                  optimizer=optimizer,
                  metrics=['accuracy'])

lstm_2 = load_model('./models/two_star.h5')

lstm_2.compile(loss='binary_crossentropy',
                  optimizer=optimizer,
                  metrics=['accuracy'])

lstm_3 = load_model('./models/three_star.h5')

lstm_3.compile(loss='binary_crossentropy',
                  optimizer=optimizer,
                  metrics=['accuracy'])

lstm_4 = load_model('./models/four_star.h5')

lstm_4.compile(loss='binary_crossentropy',
                  optimizer=optimizer,
                  metrics=['accuracy'])

lstm_5 = load_model('./models/five_star.h5')

lstm_5.compile(loss='binary_crossentropy',
                  optimizer=optimizer,
                  metrics=['accuracy'])
```

Evaluate Models

In [103]:
```
# Baseline
print(baseline.evaluate(X_baseline, y))

# LSTM
print(lstm.evaluate(X_lstm, y))

# One vs. All
one_star_ps = lstm_1.predict(X_lstm)
two_star_ps = lstm_2.predict(X_lstm)
three_star_ps = lstm_3.predict(X_lstm)
four_star_ps = lstm_4.predict(X_lstm)
five_star_ps = lstm_5.predict(X_lstm)

data = [one_star_ps.flatten(), two_star_ps.flatten(), three_star_ps.flatten(), f
cols = [1, 2, 3, 4, 5]
ps = pd.DataFrame(data=data, index=cols).T

ps["ova_pred"] = ps.idxmax(axis=1)

print([MAE(ps["ova_pred"], pd.DataFrame(data=y, columns=cols).idxmax(axis=1)), A
```

```
500/500 [==============================] - 0s 202us/step
[2.3049304752349853, 0.4480000138282776]
500/500 [==============================] - 0s 711us/step
[2.3681153812408446, 0.41600000858306885]
[1.834, 0.45]
```

Attempt Ensemble

In [104]:
```
# Baseline
baseline_preds = pd.DataFrame(baseline.predict(X_baseline), columns=cols)
baseline_preds['baseline_pred'] = baseline_preds.idxmax(axis=1)

# LSTM
lstm_preds = pd.DataFrame(lstm.predict(X_lstm), columns=cols)
lstm_preds['lstm_pred'] = lstm_preds.idxmax(axis=1)

# One vs. all
ova_preds = ps

all_preds = pd.DataFrame([baseline_preds['baseline_pred'], lstm_preds['lstm_pred
all_preds["final_pred"] = all_preds.mode(axis=1)[0]

print([MAE(all_preds["final_pred"], pd.DataFrame(data=y, columns=cols).idxmax(ax
```

```
[2.064, 0.454]
```

Misc.

In [105]:
```
sns.countplot(all_preds["final_pred"])
```

Out[105]:
```
<matplotlib.axes._subplots.AxesSubplot at 0x22300bfb6c8>
```