Using Scikit-Learn and NLTK to build a Naive Bayes Classifier that identifies subtweets

In all tables, assume:

- "➊" represents a single hashtag
- "➋" represents a single URL
- "➌" represents a single mention of username (e.g. "@noah")

Import libraries

```
%matplotlib inline
```

```
from sklearn.feature_extraction import text
from sklearn.feature_extraction.text import TfidfVectorizer
from sklearn.naive_bayes import MultinomialNB
from sklearn.pipeline import Pipeline
from sklearn.model_selection import KFold
from sklearn.metrics import classification_report, confusion_matrix, accuracy_score
from sklearn.externals import joblib
from nltk.corpus import stopwords
from random import choice
from string import punctuation

import matplotlib.pyplot as plt
import pandas as pd
import numpy as np

import scipy.stats
import itertools
import enchant
import nltk
import json
import re
```

Set up some regex patterns

```
hashtags_pattern = r'(\#[a-zA-Z0-9]+)'
```

```
urls_pattern = r'(?i)\b((?:https?://|www\d{0,3}[.]|[a-z0-9.\-]+[.][a-z]{2,4}/)(?:[^\s()<>]|\(([^\s()<>]+|(\([^\s()<>]
```

```
at_mentions_pattern = r'(?<=^|(?<=[^a-zA-Z0-9-\.]))@([A-Za-z0-9_]+)'
```

Prepare English dictionary for language detection

```
english_dict = enchant.Dict("en_US")
```

Use NLTK's tokenizer instead of Scikit's

```
tokenizer = nltk.casual.TweetTokenizer(preserve_case=False, reduce_len=True)
```

Prepare for viewing long text in CSVs and ones with really big and small numbers

```
pd.set_option("max_colwidth", 1000)
```

```
pd.options.display.float_format = "{:.4f}".format
```

Load the two data files

```
subtweets_data = [t for t in json.load(open("../data/other_data/subtweets.json"))
                  if t["tweet_data"]["user"]["lang"] == "en"
                  and t["reply"]["user"]["lang"] == "en"]
```

```
non_subtweets_data = [t for t in json.load(open("../data/other_data/non_subtweets.json"))
                      if t["tweet_data"]["user"]["lang"] == "en"
                      and t["reply"]["user"]["lang"] == "en"]
```

Only use tweets with at least 50% English words

Also, make the mentions of usernames, URLs, and hashtags generic

```
%%time
subtweets_data = [(re.sub(hashtags_pattern,
                          "➊",
                          re.sub(urls_pattern,
                                 "➋",
                                 re.sub(at_mentions_pattern,
                                        "➌",
                                        t["tweet_data"]["full_text"])))
                   .replace("\u2018", "'")
                   .replace("\u2019", "'")
                   .replace("&quot;", "\"")
                   .replace("&amp;", "&")
                   .replace("&gt;", ">")
                   .replace("&lt;", "<"))
                  for t in subtweets_data]
```

```
CPU times: user 268 ms, sys: 16.6 ms, total: 284 ms
Wall time: 297 ms
```

```
new_subtweets_data = []
for tweet in subtweets_data:
    tokens = tokenizer.tokenize(tweet)
    english_tokens = [english_dict.check(token) for token in tokens]
    percent_english_words = sum(english_tokens)/len(english_tokens)
    if percent_english_words >= 0.5:
        new_subtweets_data.append(tweet)
```

```
%%time
non_subtweets_data = [(re.sub(hashtags_pattern,
                              "❶",
                              re.sub(urls_pattern,
                                     "❷",
                                     re.sub(at_mentions_pattern,
                                            "❸",
                                            t["tweet_data"]["full_text"])))
                       .replace("\u2018", "'")
                       .replace("\u2019", "'")
                       .replace("&quot;", "\"")
                       .replace("&amp;", "&")
                       .replace("&gt;", ">")
                       .replace("&lt;", "<"))
                      for t in non_subtweets_data]
```

```
CPU times: user 418 ms, sys: 31.7 ms, total: 450 ms
Wall time: 452 ms
```

```
new_non_subtweets_data = []
for tweet in non_subtweets_data:
    tokens = tokenizer.tokenize(tweet)
    english_tokens = [english_dict.check(token) for token in tokens]
    percent_english_words = sum(english_tokens)/len(english_tokens)
    if percent_english_words >= 0.5:
        new_non_subtweets_data.append(tweet)
```

Show examples

```
print("Subtweets dataset example:")
print(choice(new_subtweets_data))
```

```
Subtweets dataset example:
My feelings are all over the place. We're supposed to be engaged and both of us being busy dosen't help. I guess
the babies just complete our little family and we'll have more time with each other when they come.😔
```

```
print("Non-subtweets dataset example:")
print(choice(new_non_subtweets_data))
```

```
Non-subtweets dataset example:
❸ Hi there! I wasn't able to get through by phone, so I thought I'd ask my MtG question here: Are you taking
preorders for booster boxes of Dominaria? If so, how much are they and can they be collected at the prerelease
event?
Thank you!
```

Find the length of the smaller dataset

```
smallest_length = len(min([new_subtweets_data, new_non_subtweets_data], key=len))
```

Cut both down to be the same length

```
subtweets_data = new_subtweets_data[:smallest_length]
```

```
non_subtweets_data = new_non_subtweets_data[:smallest_length]
```

```
print("Smallest dataset length: {}".format(len(non_subtweets_data)))
```

```
Smallest dataset length: 7837
```

Prepare data for training

```
subtweets_data = [(tweet, "subtweet") for tweet in subtweets_data]
```

```
non_subtweets_data = [(tweet, "non-subtweet") for tweet in non_subtweets_data]
```

Combine them

```
training_data = subtweets_data + non_subtweets_data
```

Create custom stop words to include generic usernames, URLs, and hashtags, as well as common English first names

```
names_lower = set([name.lower() for name in open("../data/other_data/first_names.txt").read().split("\n")])
```

```
generic_tokens = {"❶", "❷", "❸"}
```

```
stop_words = text.ENGLISH_STOP_WORDS | names_lower | generic_tokens
```

Build the pipeline

```
sentiment_pipeline = Pipeline([
    ("vectorizer", TfidfVectorizer(tokenizer=tokenizer.tokenize,
                                   ngram_range=(1, 3),
                                   stop_words=stop_words)),
    ("classifier", MultinomialNB())
])
```

K-Folds splits up and separates out 10 training and test sets from the data, from which the classifier is trained and the confusion matrix and classification reports are updated

```
text_training_data = np.array([row[0] for row in training_data])
```

```
class_training_data = np.array([row[1] for row in training_data])
```

```
num_folds=10
```

```
kf = KFold(n_splits=num_folds, random_state=42, shuffle=True)
```

```
%%time
cnf_matrix = np.zeros((2, 2), dtype=int)
for i, (train_index, test_index) in enumerate(kf.split(text_training_data)):

    text_train, text_test = text_training_data[train_index], text_training_data[test_index]
    class_train, class_test = class_training_data[train_index], class_training_data[test_index]

    sentiment_pipeline.fit(text_train, class_train)
    predictions = sentiment_pipeline.predict(text_test)

    cnf_matrix += confusion_matrix(class_test, predictions)

    print("Iteration {}".format(i+1))
    print(classification_report(class_test, predictions, digits=3))
    print("null accuracy: {:.3f}\n".format(max(pd.value_counts(pd.Series(class_test)))/float(len(class_test))))
    print("="*53)
```

```
Iteration 1
              precision    recall  f1-score   support

non-subtweet      0.732     0.644     0.685       793
    subtweet      0.676     0.759     0.715       775

 avg / total      0.704     0.701     0.700      1568

null accuracy: 0.506

=====================================================
Iteration 2
              precision    recall  f1-score   support

non-subtweet      0.688     0.631     0.658       789
    subtweet      0.655     0.710     0.681       779

 avg / total      0.672     0.670     0.670      1568

null accuracy: 0.503

=====================================================
Iteration 3
              precision    recall  f1-score   support

non-subtweet      0.703     0.685     0.694       769
    subtweet      0.704     0.721     0.712       799

 avg / total      0.703     0.703     0.703      1568

null accuracy: 0.510

=====================================================
Iteration 4
              precision    recall  f1-score   support

non-subtweet      0.731     0.639     0.682       801
    subtweet      0.667     0.755     0.708       767

 avg / total      0.700     0.696     0.695      1568

null accuracy: 0.511

=====================================================
Iteration 5
              precision    recall  f1-score   support

non-subtweet      0.708     0.656     0.681       779
    subtweet      0.683     0.732     0.707       788

 avg / total      0.695     0.694     0.694      1567

null accuracy: 0.503

=====================================================
Iteration 6
              precision    recall  f1-score   support
```

```
non-subtweet      0.684     0.662     0.673       758
    subtweet      0.693     0.713     0.703       809

 avg / total      0.688     0.689     0.688      1567

null accuracy: 0.516

=====================================================
Iteration 7
              precision    recall  f1-score   support

non-subtweet      0.699     0.630     0.662       751
    subtweet      0.688     0.750     0.717       816

 avg / total      0.693     0.692     0.691      1567

null accuracy: 0.521

=====================================================
Iteration 8
              precision    recall  f1-score   support

non-subtweet      0.733     0.643     0.685       812
    subtweet      0.661     0.748     0.702       755

 avg / total      0.698     0.694     0.693      1567

null accuracy: 0.518

=====================================================
Iteration 9
              precision    recall  f1-score   support

non-subtweet      0.731     0.642     0.683       829
    subtweet      0.646     0.734     0.687       738

 avg / total      0.691     0.685     0.685      1567

null accuracy: 0.529

=====================================================
Iteration 10
              precision    recall  f1-score   support

non-subtweet      0.707     0.681     0.694       756
    subtweet      0.713     0.737     0.725       811

 avg / total      0.710     0.710     0.710      1567

null accuracy: 0.518

=====================================================
CPU times: user 45.3 s, sys: 1.49 s, total: 46.8 s
Wall time: 51.8 s
```

See the most informative features

```python
def most_informative_features(pipeline, n=50):
    vectorizer = pipeline.named_steps["vectorizer"]
    classifier = pipeline.named_steps["classifier"]

    class_labels = classifier.classes_

    feature_names = vectorizer.get_feature_names()

    top_n_class_1 = sorted(zip(classifier.coef_[0], feature_names))[:n]
    top_n_class_2 = sorted(zip(classifier.coef_[0], feature_names))[-n:]
    return {class_labels[0]: pd.DataFrame({"Weight": [tup[0] for tup in top_n_class_1],
                                           "Feature": [tup[1] for tup in top_n_class_1]}),
            class_labels[1]: pd.DataFrame({"Weight": [tup[0] for tup in reversed(top_n_class_2)],
                                           "Feature": [tup[1] for tup in reversed(top_n_class_2)]})}
```

```
most_informative_features_all = most_informative_features(sentiment_pipeline)
```

```
most_informative_features_non_subtweet = most_informative_features_all["non-subtweet"]
```

```
most_informative_features_subtweet = most_informative_features_all["subtweet"]
```

```
most_informative_features_non_subtweet.join(most_informative_features_subtweet,
                                            lsuffix=" (Non-subtweet)",
                                            rsuffix=" (Subtweet)")
```

	Feature (Non-subtweet)	Weight (Non-subtweet)	Feature (Subtweet)	Weight (Subtweet)
0	! ! &	-12.6640	.	-7.5326
1	! ! (	-12.6640	,	-7.9221
2	! !)	-12.6640	people	-8.3929
3	! ! .	-12.6640	?	-8.4622
4	! ! 100	-12.6640	don't	-8.5613
5	! ! 15	-12.6640	like	-8.5917
6	! ! 3	-12.6640	"	-8.6097
7	! ! 5	-12.6640	just	-8.6781
8	! ! 8am	-12.6640	i'm	-8.6996
9	! ! :)	-12.6640	!	-8.9060
10	! ! ;)	-12.6640	it's	-8.9756
11	! ! absolutely	-12.6640	...	-9.0457
12	! ! amazing	-12.6640	you're	-9.0515
13	! ! ask	-12.6640	:	-9.0737
14	! ! awesome	-12.6640	know	-9.0953
15	! ! big	-12.6640	twitter	-9.1468
16	! ! bite	-12.6640	friends	-9.1676
17	! ! close	-12.6640	”	-9.2655
18	! ! collection	-12.6640	“	-9.2730
19	! ! come	-12.6640	time	-9.2904
20	! ! don't	-12.6640	want	-9.2949
21	! ! enter	-12.6640	u	-9.3026
22	! ! epic	-12.6640	really	-9.3542
23	! ! extremely	-12.6640	shit	-9.3723

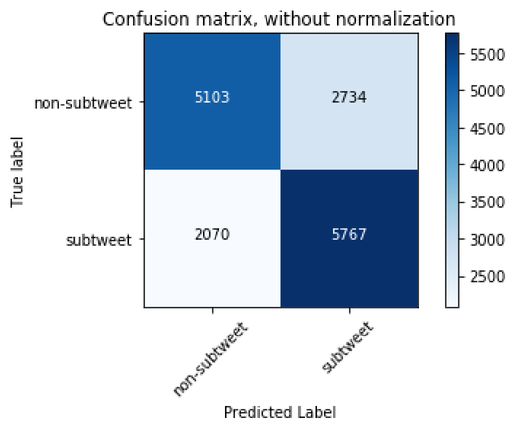
	Feature (Non-subtweet)	Weight (Non-subtweet)	Feature (Subtweet)	Weight (Subtweet)
24	! ! family	-12.6640	good	-9.4043
25	! ! finally	-12.6640	think	-9.4184
26	! ! glasgow	-12.6640	make	-9.4248
27	! ! guess	-12.6640	😂	-9.4359
28	! ! happy	-12.6640	can't	-9.4544
29	! ! hardest	-12.6640	*	-9.5023
30	! ! he's	-12.6640	need	-9.5308
31	! ! homeland	-12.6640	fuck	-9.5328
32	! ! isn't	-12.6640	tweet	-9.5364
33	! ! it's	-12.6640	say	-9.5649
34	! ! know	-12.6640	stop	-9.6284
35	! ! like	-12.6640	)	-9.6436
36	! ! lol	-12.6640	-	-9.6666
37	! ! looking	-12.6640	/	-9.6850
38	! ! looks	-12.6640	lol	-9.6878
39	! ! lov	-12.6640	person	-9.6952
40	! ! loved	-12.6640	fucking	-9.7133
41	! ! maaawd	-12.6640	life	-9.7144
42	! ! maga	-12.6640	hate	-9.7286
43	! ! make	-12.6640	got	-9.7451
44	! ! maybe	-12.6640	y'all	-9.7635
45	! ! need	-12.6640	'	-9.7664
46	! ! omfg	-12.6640	(	-9.7790
47	! ! open	-12.6640	! !	-9.7901
48	! ! packed	-12.6640	thing	-9.7926
49	! ! people	-12.6640	@	-9.7958

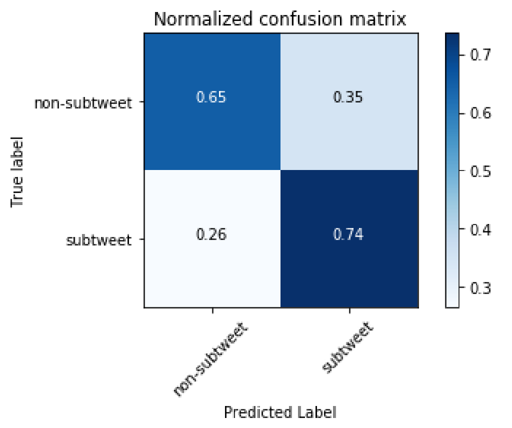
Define function for visualizing confusion matrices

```python
def plot_confusion_matrix(cm, classes, normalize=False,
                          title="Confusion Matrix", cmap=plt.cm.Blues):
    if normalize:
        cm = cm.astype("float") / cm.sum(axis=1)[:, np.newaxis]

    plt.imshow(cm, interpolation="nearest", cmap=cmap)
    plt.title(title)
    plt.colorbar()
    tick_marks = np.arange(len(classes))
    plt.xticks(tick_marks, classes, rotation=45)
    plt.yticks(tick_marks, classes)

    fmt = ".2f" if normalize else "d"
    thresh = cm.max() / 2.
    for i, j in itertools.product(range(cm.shape[0]), range(cm.shape[1])):
        plt.text(j, i, format(cm[i, j], fmt),
                 horizontalalignment="center",
                 color="white" if cm[i, j] > thresh else "black")

    plt.tight_layout()
    plt.ylabel("True label")
    plt.xlabel("Predicted Label")
```

Show the matrices

```
class_names = ["non-subtweet", "subtweet"]

np.set_printoptions(precision=2)

plt.figure()
plot_confusion_matrix(cnf_matrix, classes=class_names,
                      title='Confusion matrix, without normalization')

plt.figure()
plot_confusion_matrix(cnf_matrix, classes=class_names, normalize=True,
                      title='Normalized confusion matrix')

plt.show()
```





Update matplotlib style

```
plt.style.use("fivethirtyeight")
```

Save the classifier for another time

```
joblib.dump(sentiment_pipeline, "../data/other_data/subtweets_classifier.pkl");
```

Print tests for the classifier

```
def tests_dataframe(tweets_dataframe, text_column="SentimentText", sentiment_column="Sentiment"):
    predictions = sentiment_pipeline.predict_proba(tweets_dataframe[text_column])
    negative_probability = predictions[:, 0].tolist()
    positive_probability = predictions[:, 1].tolist()
    return pd.DataFrame({"tweet": tweets_dataframe[text_column],
                         "sentiment_score": tweets_dataframe[sentiment_column],
                         "subtweet_negative_probability": negative_probability,
                         "subtweet_positive_probability": positive_probability}).sort_values(by="subtweet_positive_pr
                                                                                              ascending=False)
```

Make up some tweets

```
test_tweets = ["Some people don't know their place.",
               "Isn't it funny how some people don't know their place?",
               "How come you people act like this?",
               "You're such a nerd.",
               "I love Noah, he's so cool.",
               "Who the heck is Noah?",
               "This is a @NoahSegalGould subtweet. Go check out https://segal-gould.com.",
               "This is a subtweet.",
               "Hey @jack!",
               "Hey Jack!",
               "http://www.google.com"]
```

Make a dataframe from the list

```
test_tweets_df = pd.DataFrame({"Tweet": test_tweets, "Sentiment": [None]*len(test_tweets)})
```

Remove usernames, URLs, and hashtags

```
test_tweets_df["Tweet"] = test_tweets_df["Tweet"].str.replace(hashtags_pattern, "➊")
```

```
test_tweets_df["Tweet"] = test_tweets_df["Tweet"].str.replace(urls_pattern, "➋")
```

```
test_tweets_df["Tweet"] = test_tweets_df["Tweet"].str.replace(at_mentions_pattern, "➌")
```

Print the tests

```
tests_dataframe(test_tweets_df, text_column="Tweet",
               sentiment_column="Sentiment").drop(["sentiment_score",
                                                   "subtweet_negative_probability"], axis=1)
```

	subtweet_positive_probability	tweet
0	0.7802	Some people don't know their place.
1	0.7730	Isn't it funny how some people don't know their place?
2	0.7179	How come you people act like this?
3	0.6903	You're such a nerd.
4	0.5781	I love Noah, he's so cool.

	subtweet_positive_probability	tweet
10	0.4981	❷
5	0.4625	Who the heck is Noah?
6	0.4487	This is a ❸ subtweet. Go check out ❷.
7	0.4425	This is a subtweet.
8	0.2996	Hey ❸!
9	0.2996	Hey Jack!

Tests on friends' tweets

Aaron

```
aaron_df = pd.read_csv("../data/data_for_testing/friends_data/akrapf96_tweets.csv").dropna()
aaron_df["Sentiment"] = None
```

Remove usernames, URLs, and hashtags

```
aaron_df["Text"] = aaron_df["Text"].str.replace(hashtags_pattern, "❶")
```

```
aaron_df["Text"] = aaron_df["Text"].str.replace(urls_pattern, "❷")
```

```
aaron_df["Text"] = aaron_df["Text"].str.replace(at_mentions_pattern, "❸")
```

```
aaron_df = tests_dataframe(aaron_df, text_column="Text",
                           sentiment_column="Sentiment").drop(["sentiment_score",
                                                               "subtweet_negative_probability"], axis=1)
```

```
aaron_df.to_csv("../data/data_from_testing/friends_data/akrapf96_tests.csv")
```

```
aaron_df.head(10)
```

	subtweet_positive_probability	tweet
2092	0.8578	I hate when people overuse emojis
2137	0.8442	Also you don't need to resort to social media 24/7 to complain about your very privileged life ¯_(ツ)_/¯
2151	0.8366	When I try to be supportive and caring I get ignored and then I'm told I'm not being supportive or caring ¯_(ツ)_/¯
2134	0.8177	What he doesn't know (unless he stalks my twitter which I know he does) is that I have fake accounts following all his social media
181	0.8143	I often obsess when texting older people if they will think less of me for saying "LOL" so I say "haha" instead but my mom just texting me "LOL" so maybe I've been overthinking this?
1510	0.8076	If you don't have tweet notifications turned on for me are we really friends

	subtweet_positive_probability	tweet
658	0.8062	I wonder how many animal social media accounts I follow across every platform
2076	0.8027	I still don't understand why my brother feels a need to literally narrate his life on Twitter. Nobody cares when you go to sleep or wake up
1519	0.8013	Is it weird how my mind designates which social media specific content belongs on? Like this tweet wouldn't make sense to me on facebook
2319	0.8005	Sometimes I wonder if people don't realize the 140 character limit and try to type a really long message and end up having it get cut off at

```
aaron_df_for_plotting = aaron_df.drop(["tweet"], axis=1)
```

Julia

```
julia_df = pd.read_csv("../data/data_for_testing/friends_data/juliaeberry_tweets.csv").dropna()
julia_df["Sentiment"] = None
```

Remove usernames, URLs, and hashtags

```
julia_df["Text"] = julia_df["Text"].str.replace(hashtags_pattern, "❶")
```

```
julia_df["Text"] = julia_df["Text"].str.replace(urls_pattern, "❷")
```

```
julia_df["Text"] = julia_df["Text"].str.replace(at_mentions_pattern, "❸")
```

```
julia_df = tests_dataframe(julia_df, text_column="Text",
                          sentiment_column="Sentiment").drop(["sentiment_score",
                                                              "subtweet_negative_probability"], axis=1)
```

```
julia_df.to_csv("../data/data_from_testing/friends_data/juliaeberry_tests.csv")
```

```
julia_df.head(10)
```

	subtweet_positive_probability	tweet
3197	0.8674	unpopular twitter opinion I don't like christine sudoku and elijah whatever and I don't think they're funny
3613	0.8566	don't follow bachelor contestants u liked on insta bc it will just make u hate them for being annoying and unoriginal ❶
2325	0.8399	I love seeing people I knew from hs at the gym! and by that I mean don't talk to me don't even look at me
1555	0.8317	tbt to when ❸ are real trash out of the garbage
3913	0.8153	tfw ur anxiety kills ur appetite but you can't do anything done bc ur still hungry so u just get more anxiety ❶

	subtweet_positive_probability	tweet
2235	0.8152	david mitchell said the world is full of people who want to make people who don't want to dance dance....
1450	0.8129	between this is just to say and sophia the robot memes, twitter has been fucking On recently
3859	0.8108	I don't really tmi about volleyball on twitter but I wish I could bc I could vent for hours about how this sport makes me feel lyk trash
2970	0.8066	funny how some people have suddenly become serious ""academics"" and think they're amazingly intelligent now....try no bitch u fake as fuck
3348	0.8026	one critique I have of westworld: there are too many boring white guys with beards and it's hard to tell them apart

```
julia_df_for_plotting = julia_df.drop(["tweet"], axis=1)
```

Noah

```
noah_df = pd.read_csv("../data/data_for_testing/friends_data/noahsegalgould_tweets.csv").dropna()
noah_df["Sentiment"] = None
```

Remove usernames, URLs, and hashtags

```
noah_df["Text"] = noah_df["Text"].str.replace(hashtags_pattern, "❶")
```

```
noah_df["Text"] = noah_df["Text"].str.replace(urls_pattern, "❷")
```

```
noah_df["Text"] = noah_df["Text"].str.replace(at_mentions_pattern, "❸")
```

```
noah_df = tests_dataframe(noah_df, text_column="Text",
                          sentiment_column="Sentiment").drop(["sentiment_score",
                                                              "subtweet_negative_probability"], axis=1)
```

```
noah_df.to_csv("../data/data_from_testing/friends_data/noahsegalgould_tests.csv")
```

```
noah_df.head(10)
```

	subtweet_positive_probability	tweet
2022	0.8972	you may think you're cool but unless you're friends with my friends you're not actually as cool as you could be
1689	0.8490	linkedin is better than twitter.\ndon't @ me.
1716	0.8412	If you don't make your meatloaf with ketchup don't bother talking to me
2027	0.8372	IF U CALL URSELF A WEEB BUT DONT HAVE ANIME PROF PICS ON ALL SOCIAL MEDIA\n DELETE UR ACCOUNTS
1760	0.8172	don't ever talk to me or my hamartia ever again

	subtweet_positive_probability	tweet
340	0.8130	Twitter changed the way bots download tweets and now my friends’ twitter bots can’t be updated unless they give me sensitive information
291	0.8129	if you've still got tweet notifications on for me, I'm sorry, this is a subtweet
2523	0.8090	Instead of posting several vague tweets revolving around my issues of self-worth I'll just ask this: Who decides how good a friend I am?
1797	0.8083	don't @ ❷
1242	0.8020	stupid pet peeve of the evening:\nsaying "greater than" aloud 5 times sounds stupid\nso why type >>>>>

```
noah_df_for_plotting = noah_df.drop(["tweet"], axis=1)
```

Rename the columns for later

```
aaron_df_for_plotting_together = aaron_df_for_plotting.rename(columns={"subtweet_positive_probability": "Aaron"})
```

```
julia_df_for_plotting_together = julia_df_for_plotting.rename(columns={"subtweet_positive_probability": "Julia"})
```

```
noah_df_for_plotting_together = noah_df_for_plotting.rename(columns={"subtweet_positive_probability": "Noah"})
```

Prepare statistics on friends' tweets

```
friends_df = pd.concat([aaron_df_for_plotting_together,
                        julia_df_for_plotting_together,
                        noah_df_for_plotting_together], ignore_index=True)
```

```
friends_df.describe()
```

	Aaron	Julia	Noah
count	2640.0000	4356.0000	2814.0000
mean	0.5069	0.5162	0.5063
std	0.1147	0.1014	0.1078
min	0.0953	0.1522	0.1506
25%	0.4295	0.4476	0.4326
50%	0.5027	0.5164	0.5017
75%	0.5837	0.5818	0.5736
max	0.8578	0.8674	0.8972

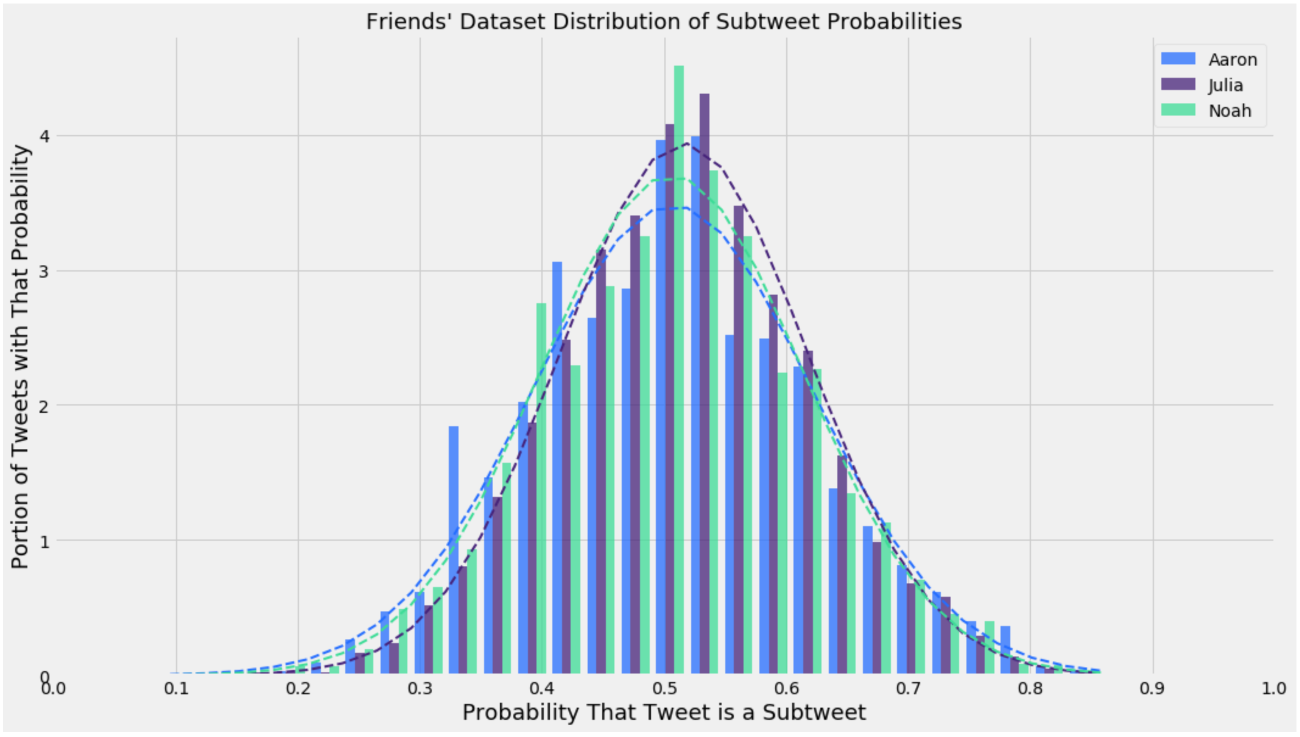
```
aaron_mean = friends_df.describe().Aaron[1]
aaron_std = friends_df.describe().Aaron[2]

julia_mean = friends_df.describe().Julia[1]
julia_std = friends_df.describe().Julia[2]
```

```
noah_mean = friends_df.describe().Noah[1]
noah_std = friends_df.describe().Noah[2]
```

Plot all the histograms

```
%%time
fig = plt.figure(figsize=(16, 9))
ax = fig.add_subplot(111)

n, bins, patches = ax.hist([aaron_df_for_plotting.subtweet_positive_probability,
                            julia_df_for_plotting.subtweet_positive_probability,
                            noah_df_for_plotting.subtweet_positive_probability],
                           bins="scott",
                           color=["#256EFF", "#46237A", "#3DDC97"],
                           density=True,
                           label=["Aaron", "Julia", "Noah"],
                           alpha=0.75)

aaron_line = scipy.stats.norm.pdf(bins, aaron_mean, aaron_std)
ax.plot(bins, aaron_line, "--", color="#256EFF", linewidth=2)

julia_line = scipy.stats.norm.pdf(bins, julia_mean, julia_std)
ax.plot(bins, julia_line, "--", color="#46237A", linewidth=2)

noah_line = scipy.stats.norm.pdf(bins, noah_mean, noah_std)
ax.plot(bins, noah_line, "--", color="#3DDC97", linewidth=2)

ax.set_xticks([float(x/10) for x in range(11)], minor=False)
ax.set_title("Friends' Dataset Distribution of Subtweet Probabilities", fontsize=18)
ax.set_xlabel("Probability That Tweet is a Subtweet", fontsize=18)
ax.set_ylabel("Portion of Tweets with That Probability", fontsize=18)

ax.legend()

plt.show()
```

```
/Users/Noah/anaconda/envs/work/lib/python3.6/site-packages/numpy/core/fromnumeric.py:52: FutureWarning: reshape is
deprecated and will raise in a subsequent release. Please use .values.reshape(...) instead
  return getattr(obj, method)(*args, **kwds)
```



```
CPU times: user 617 ms, sys: 40.7 ms, total: 658 ms
Wall time: 649 ms
```

Statisitics on training data

Remove mentions of usernames for these statistics

```
training_data = [" ".join([token for token in tokenizer.tokenize(pair[0]) if "@" not in token])
                 for pair in training_data]
```

Lengths (Less than or equal to 280 characters and greater than or equal to 5 characters)

```
length_data = [len(tweet) for tweet in training_data]
```

```
length_data_for_stats = pd.DataFrame({"Length": length_data, "Tweet": training_data})
```

```
# length_data_for_stats = length_data_for_stats[length_data_for_stats["Length"] <= 280]
```

```
# length_data_for_stats = length_data_for_stats[length_data_for_stats["Length"] >= 5]
```

```
length_data = length_data_for_stats.Length.tolist()
```

Top 10 longest tweets

```
length_data_for_stats.sort_values(by="Length", ascending=False).head(10)
```

	Length	Tweet
14329	303	from 10/18 / 15 when he 1st played hurt & began noticeably throwing w poor mechanics thru end of his injured 2016 yr , luck's stats were as good as his healthiest / best 2013-2014 yrs : - injured : 61 % comp , 7.4 ypa , 93 rtg , 41:18 td : int - healthy : 61 % comp , 7.2 ypa , 92 rtg , 63:25 td : int ❷
4476	302	in situations of power imbalance , wealth inequality , unequal access to ... everything-can ' we ' drop the ' we ' - because it really means you not me . when . you . pretend . that . we . all . share . same . interests . you . are . helping . the . most . powerful . oppress . the . least . powerful .
8001	300	hotel elevator earlier today : i get in , a young man and a young woman already in the car . me : " good morning , both . " woman : " good morning . " man , clearly writhing , not wanting to say anything but caught in a vortex due to the young woman's response . ten seconds later : " ... morning . "
15228	299	" it is a key agreement that shapes today's globalisation " - frau merkel on the paris ' agreement ' . climatefraud-a contrived tool of the deadly eu / un-centric marxist-globalist / islamist alliance , to wealth transfer & to create such energy poverty , that sovereignwesterndemocracy implodes . ❷
14724	299	pentagon : master sergeant jonathan j . dunbar , assigned to headquarters , u . s . army special operations command , fort bragg , n . c . , was kia mar . 30 , while deployed in support of operation inherent resolve . dunbar died from wounds received during combat operations near manbij , syria . ❷

	Length	Tweet
6017	299	person : * criticizes my writing * me : yup , they're right , 100 percent , spot on , very valid , absolutely agree person : * compliments my writing * me : ? ? ? did they read something else ? ? ? are they lying ? ? ? are they drunk ? ? ? i don't know what to do with this ? please just insult me ?
8702	298	i've fallen into a rabbit hole of goals from that 2016 run . faves : 1) crosby's goal against raanta in rd . 1 . 2) cullen's goal in ny . third period . tie game . 3) fehr's goal in game 2 vs . washington . 4) rust's breakaway in game 6 vs . tampa . 5) fehr's game 5 insurance goal vs . sj . ❷
5265	296	me : " we can't deviate from the clinical policies the client's medical team chose " coworker : " well we'll ask the cto " m : " okay but he's in agreement too " c : " i don't want to talk to you . our medical licenses are on the line " m : " no ... they aren't . you didn't choose the policies "
8607	296	the first-time event , bucky's yard sale , is april 12 and 13 from 9am - 2pm at etsu in the quad . donations of clothing , shoes accessories , and other cool things are needed ! drop-off bins are in the cpa , outside of sorc a in the culp , and in centennial , governors , stone , and clement . ❷
9006	296	❶ campaign ideas i can't get out of my head : 💠 gothic monster hunting (e . g . krevborna , ravenloft , solomon kane) 💠 aetherpunk intrigue (e . g . kaladesh , lantan , eberron) 💠 megadungeon exploration (e . g . doomvault , rappan athuk) merging them would not work well . need moar time .

Top 10 shortest tweets

```
length_data_for_stats.sort_values(by="Length", ascending=True).head(10)
```

	Length	Tweet
7699	1	a
2038	2	ha
5896	2	uh
3473	2	no
3785	3	ugh
6676	3	i -
4596	3	die
9177	4	go ❷
636	4	us ❷
648	4	oh ❷

Tweet length statistics

```
length_data_for_stats.describe()
```

	Length
count	15674.0000
mean	109.5542
std	75.5204

	Length
min	1.0000
25%	50.0000
50%	89.0000
75%	154.0000
max	303.0000

Punctuation

```
punctuation_data = [len(set(punctuation).intersection(set(tweet))) for tweet in training_data]
```

```
punctuation_data_for_stats = pd.DataFrame({"Punctuation": punctuation_data, "Tweet": training_data})
```

Top 10 most punctuated tweets

```
punctuation_data_for_stats.sort_values(by="Punctuation", ascending=False).head(10)
```

	Punctuation	Tweet
8957	10	going to go ahead and crown myself the absolute emperor of finding things on menus that sound interesting , deciding i would like to try them , then being told " i'm sorry sir , that's actually not available ... " [then why the # $ % is it on your menuuu - -]
13365	9	billboard hot 100 : ❶ (- 3) tell me you love me , ❸ [19 weeks] . * peak : ❶ *
11066	9	not every aspect worked , but overall had a lot of fun at ❶ . and also (minor spoiler-ish thingy below) ... ... maybe the best " single use of the f word in a pg - 13 movie " ever ? (didn't hurt that it was connected to a great love of mine !)
11845	9	tucker carlson tonight & tfw you're asking about america but you're scolded it's really about israel ... tucker : " what is the american national security interest ... in syria ? " sen . wicker (r): " well , if you care about israel ... " that was the exact question & answer shocking ❷
11718	9	self-employed people : have you ever turned to social media to call out a client who is many weeks / months delinquent on a payment ? (obviously , you're probably burning a bridge with that move , but if they don't pay ...)
909	9	twitter user : " if you're [oppressed identity / status / role] , no need to read this ; if you're [privileged identity / status / role] , read it " the parts of my brain responsible for assuring my physical & emotional safety as a brainwashing survivor with 3000 diseases : ❷
6725	9	4 - yo : daddeee ! ? let's play ! me : ok , baby . 4yo : you play w / her . put a dress on her daddeee . me : ok . * puts doll in dollhouse * 4yo : she doesn't go there ! !
13933	9	feds had one chance to search cohen's places ! since he , alone & w / trump , has been busy w / so much possibly criminal activity , searches covered the whole enchilada : bank fraud , tax crimes , $ laundering & 2016 election-related crimes , including payoffs that could be fec violations . ❷
13817	8	print orders are available in my etsy store : ❷ (* ´ ∀ ` *) i am very proud of these prints and i'm very happy with their quality ! ! i hope you like them . this is a great way to support my works (。・ ω ・ 。) ノ ♡ rt and shares are always appreciated 💕 ❷

	Punctuation	Tweet
14623	8	park jimin fancafe 01.04 . 2018 { 12:30 am kst } i left the dorm , hoseok will be alone in the room , i don't know what is army anymore you're all just from the past bye don't come to me when u see me in the street & say jimin because ima punch u in the face ❶_we_are_beardtan

Tweets punctuation statistics

```
punctuation_data_for_stats.describe()
```

	Punctuation
count	15674.0000
mean	1.8610
std	1.5408
min	0.0000
25%	1.0000
50%	2.0000
75%	3.0000
max	10.0000

Stop words

```
stop_words_data = [len(set(stopwords.words("english")).intersection(set(tweet.lower())))
                   for tweet in training_data]
```

```
stop_words_data_for_stats = pd.DataFrame({"Stop words": stop_words_data, "Tweet": training_data})
```

Top 10 tweets with most stop words

```
stop_words_data_for_stats.sort_values(by="Stop words", ascending=False).head(10)
```

	Stop words	Tweet
0	8	i don't yet have adequate words to do so , but someday i wanna write about the beautiful dance which happens in google docs between a writer & a good editor working simultaneously towards a deadline . when it's working , it's a beautiful dance — though no one really sees it .
9062	8	❸ too fine .. ima need him to have a show in a city near me 😩
9033	8	how is this still a " phase " if i'm voluntarily putting myself through a second , more intense puberty ? ? 🤔
9035	8	the role of dag rod rosenstein will be an oscar winner in the future film about the trump presidency . i'd like the story of the first few months to be told through the eyes of the bewildered sean spicer .
9038	8	done watching ' hacksaw ridge ' . if there's one thing i learned from that movie , it is simply , have faith in god .

	Stop words	Tweet
9039	8	i feel people who can't celebrate or at the very least respect cardi b's success have never watched the grind from the ground up . they can't understand that her work ethic has gotten her where she is now . you don't have to stand for what's she's about but she's worked for it
9040	8	icymi : dolphins need to improve their 2nd round draft picks : ❷
9041	8	another republican who wants us back in syria but doesn't want to vote for it . does the country support america going in alone ? ❷
9043	8	you ever just have your phone in your hand and then you hand just decides it doesn't want to hold it anymore and throws it in the ground .
9044	8	footage from the night of kenneka jenkins passing . please pass this on these two men were working the night she passed and were seen following her in the hallway ! ! ! police need to ask them what was in this bag . ❸ ❷

Top 10 tweets with fewest stop words

```
stop_words_data_for_stats.sort_values(by="Stop words", ascending=True).head(10)
```

	Stop words	Tweet
8290	0	24 ❷
9100	0	... ❷
958	0	luv u
14086	0	❶ well ...
3785	0	ugh
3632	0	... ❷
11925	0	fuck ❷
3455	0	fuck ... ❷
1662	0	uh ❷
5896	0	uh

Tweets stop words statistics

```
stop_words_data_for_stats.describe()
```

	Stop words
count	15674.0000
mean	7.1504
std	1.3123
min	0.0000
25%	7.0000
50%	8.0000

	Stop words
75%	8.0000
max	8.0000

Unique words (at least 2)

```
unique_words_data = [len(set(tokenizer.tokenize(tweet))) for tweet in training_data]
```

```
unique_words_data_for_stats = pd.DataFrame({"Unique words": unique_words_data, "Tweet": training_data})
```

```
# unique_words_data_for_stats = unique_words_data_for_stats[unique_words_data_for_stats["Unique words"] >= 2]
```

```
unique_words_data = unique_words_data_for_stats["Unique words"].tolist()
```

Top 10 tweets with most unique words

```
unique_words_data_for_stats.sort_values(by="Unique words", ascending=False).head(10)
```

	Tweet	Unique words
13936	give away ! the rules are really easy , all you have to do is : 1 . must be following me (i check) 2 . rt and fav this tweet 3 . tag your mutuals / anyone 4 . only 1 winner ! 5 . i ship worldwide ;) it ends in 8th may 2018 or when this tweet hit 2k rt and like ! good luck ! ❤️ ❷	60
4881	got into a tepid back nd forth w / a uknowwhoaj + columnist bc i said they steal their " hot takes " from blk twitter & alike . wallahi my bdeshi ass did not sign up 4 this app to be called asinine by a 30yrold pakistani whos whole politics is post colonial memes for oriental minded t -	57
7013	crazy how wrong u can be about someone . a girl i graduated w / was always doing drugs & got pregnant at 16 . i assumed she'd end up being a loser but it turn out she now has 4 beautiful kids & is making over $ 4,500 / month just off of child support payments from the 3 different dads	57
11542	thought i'd bring this back ... ❶ and no , i'm not talking about myself here . i wish just once i'd be so bored with my life that i'd find the time to bash people / celebs i don't like .. i mean if i despise someone that much , why still watch his / her every move ? 🤦 ♀ ❷	57
13339	- many 👮 ♂ suffer in silence , not always by choice but by design ! ❶ can be a career killer & worse many pd's do not see p . t . s . d as an insured disability ; this has to change 🆘 - hiding mine for 3 years made my ❶ unbearable ! please help us ❶ & ❶ ⚖️ ❷	56
13107	❸ missed meeting rey , i left at 1:30 (5th in line , for 2 hrs) so i didn't miss my other event . am i able to get a refund for the prepaid that i paid for the combo ? i know it wasn't your guys fault , but if he was gonna show up later then 12 i wouldn't have bought it .	55
13567	in loving memory of 21 yrs , my late husband i took off life support 1 yr ago this evening . the hardest thing i have ever had to do other than take your ashes to co . the memories of your 40 diff marriage proposals , i think of today . i love you & semper fi , sgt . chris ! ❤️ 🇺 🇸 ❷	55
8413	i was born at 8: 48 in the morning 32 years ago . only one person calls me at that time every year and that is my mother . since the stroke she has forgotten so much . i didn't expect a call , but like clock work the phone rang . i got hit hard with the feels right now . thanks mom 💙 ❷	55

	Tweet	Unique words
14327	never thought i was gonna kick half team but damn ... i guess i'll do it smh should've let me know so i could find some active players .. ppl now a days cant be trusted “ oh i'm active ” fuck you m8 ! ! ! y'all aren't active for shit . btw sorry if i'm mad ... but im mad 😡 ❶ ❷	55
12224	what's the one thing you hope for your character (s) to have / retain in smash 5 ? no matter what changes , i hope playing sonic feels just as free and enjoyable . i love being able to freely move anywhere in his cool blue style (hoping shadow has a fiercer & darker version of this)	55

Top 10 tweets with fewest unique words

```
unique_words_data_for_stats.sort_values(by="Unique words", ascending=True).head(10)
```

	Tweet	Unique words
2353	catfish	1
975	ginger	1
933	assumptions	1
6106	annoying	1
2525	bitch	1
7702	rude	1
2342	corny	1
7699	a	1
2038	ha	1
2351	soft	1

Tweets unique words statistics

```
unique_words_data_for_stats.describe()
```

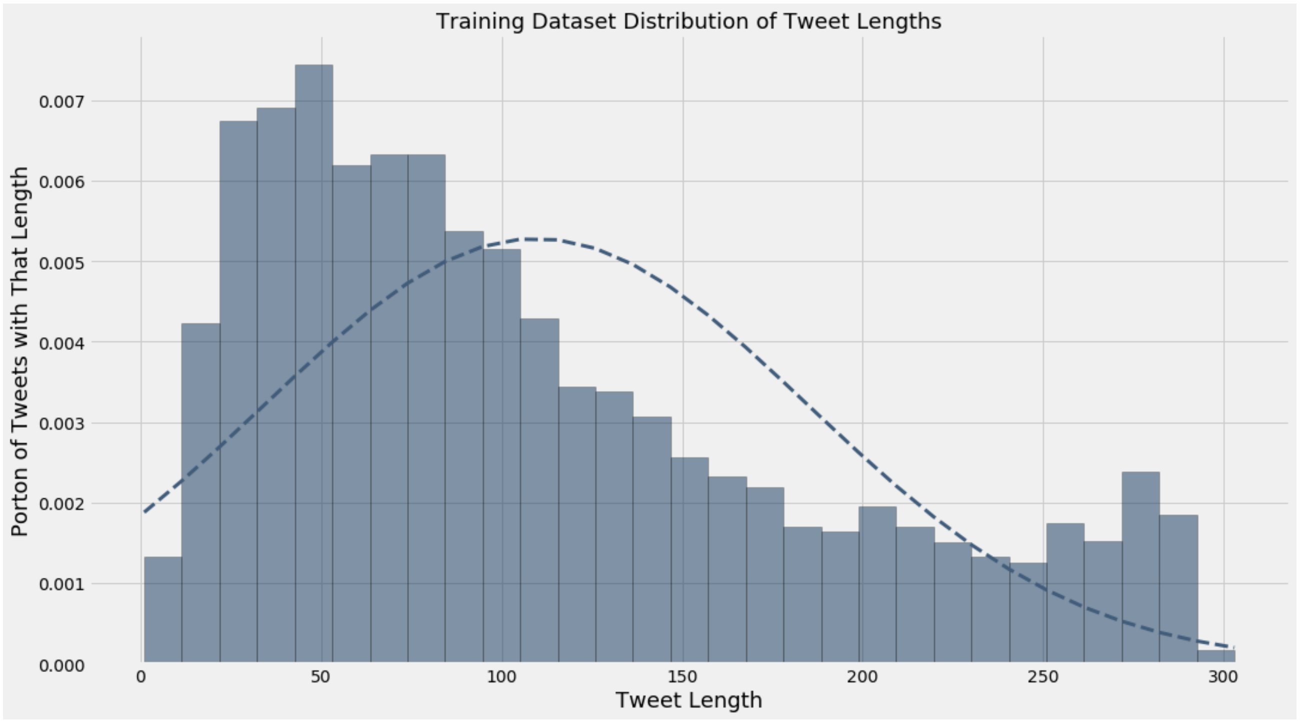
	Unique words
count	15674.0000
mean	19.8939
std	11.9839
min	1.0000
25%	10.0000
50%	17.0000
75%	28.0000
max	60.0000

Unique words

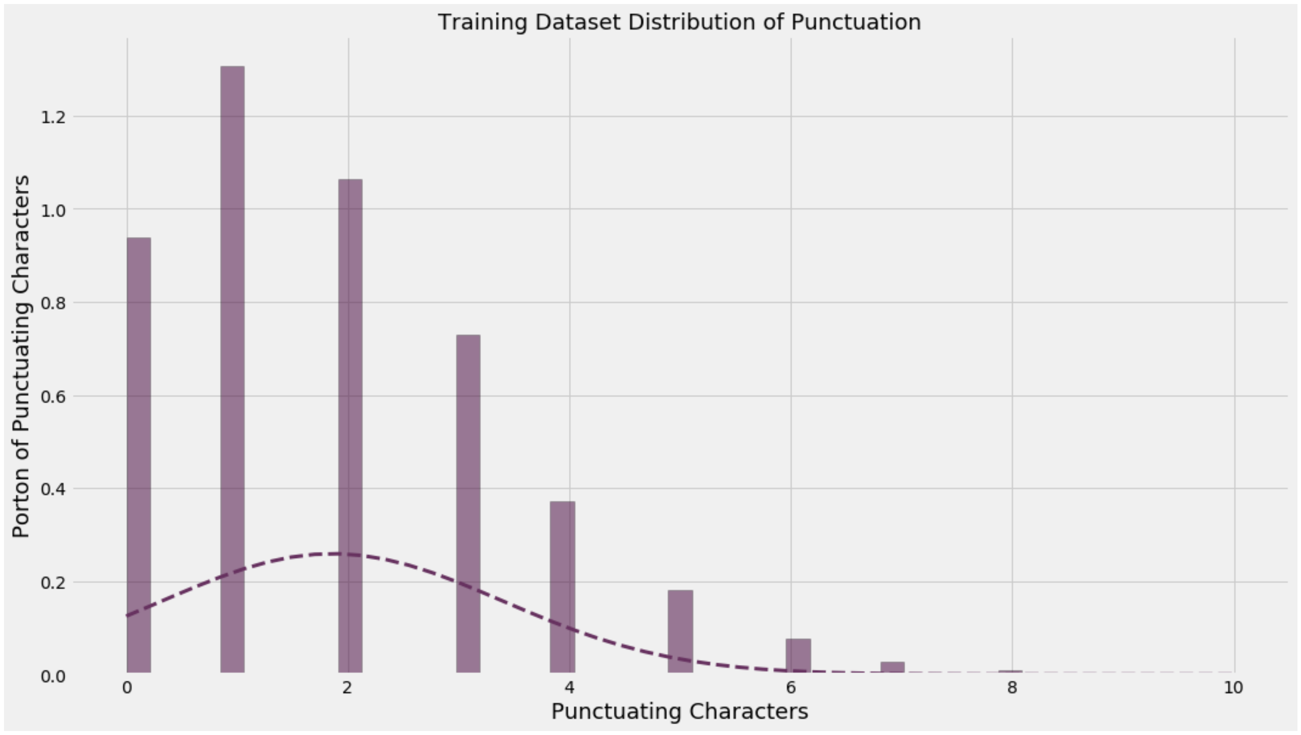
Plot them

```
length_mean = length_data_for_stats.describe().Length[1]
length_std = length_data_for_stats.describe().Length[2]
```

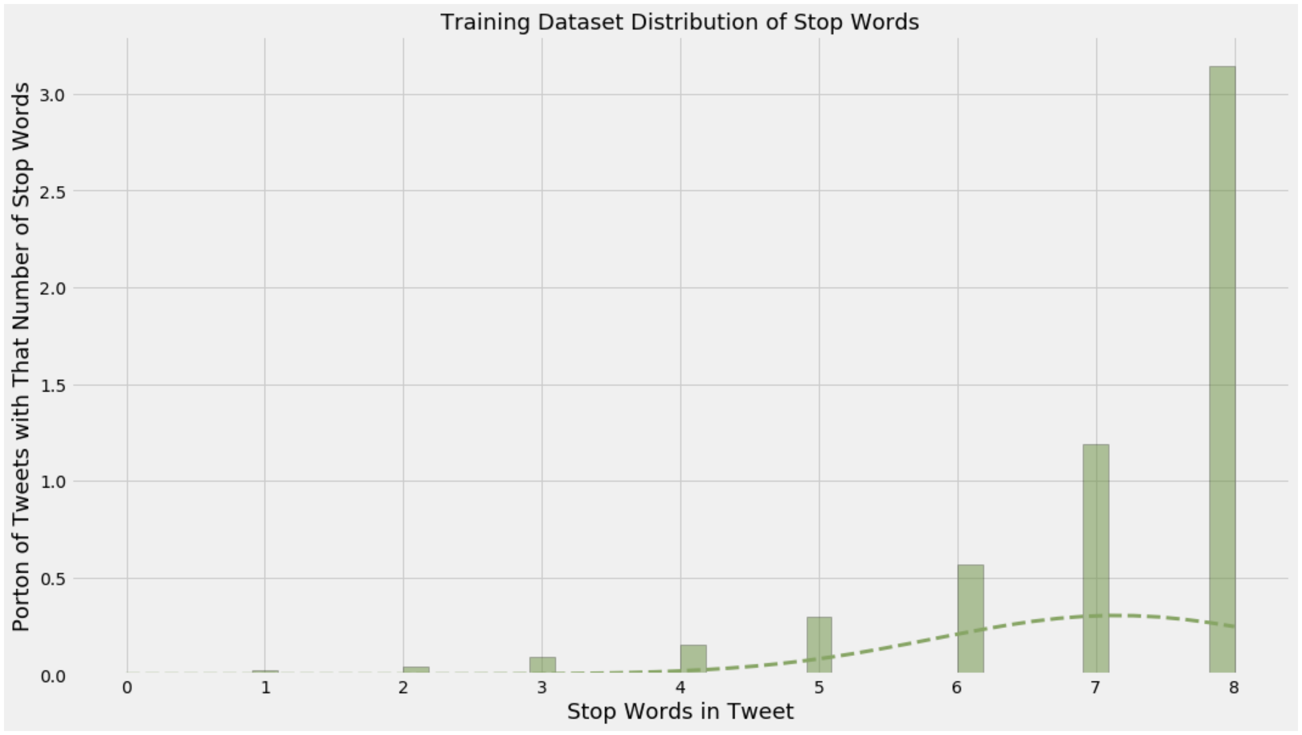
```
fig = plt.figure(figsize=(16, 9))
ax = fig.add_subplot(111)

n, bins, patches = ax.hist(length_data,
                           bins="scott",
                           edgecolor="black",
                           density=True,
                           color="#12355b",
                           alpha=0.5)

length_line = scipy.stats.norm.pdf(bins, length_mean, length_std)
ax.plot(bins, length_line, "--", linewidth=3, color="#415d7b")

ax.set_title("Training Dataset Distribution of Tweet Lengths", fontsize=18)
ax.set_xlabel("Tweet Length", fontsize=18);
ax.set_ylabel("Porton of Tweets with That Length", fontsize=18);

plt.show()
```



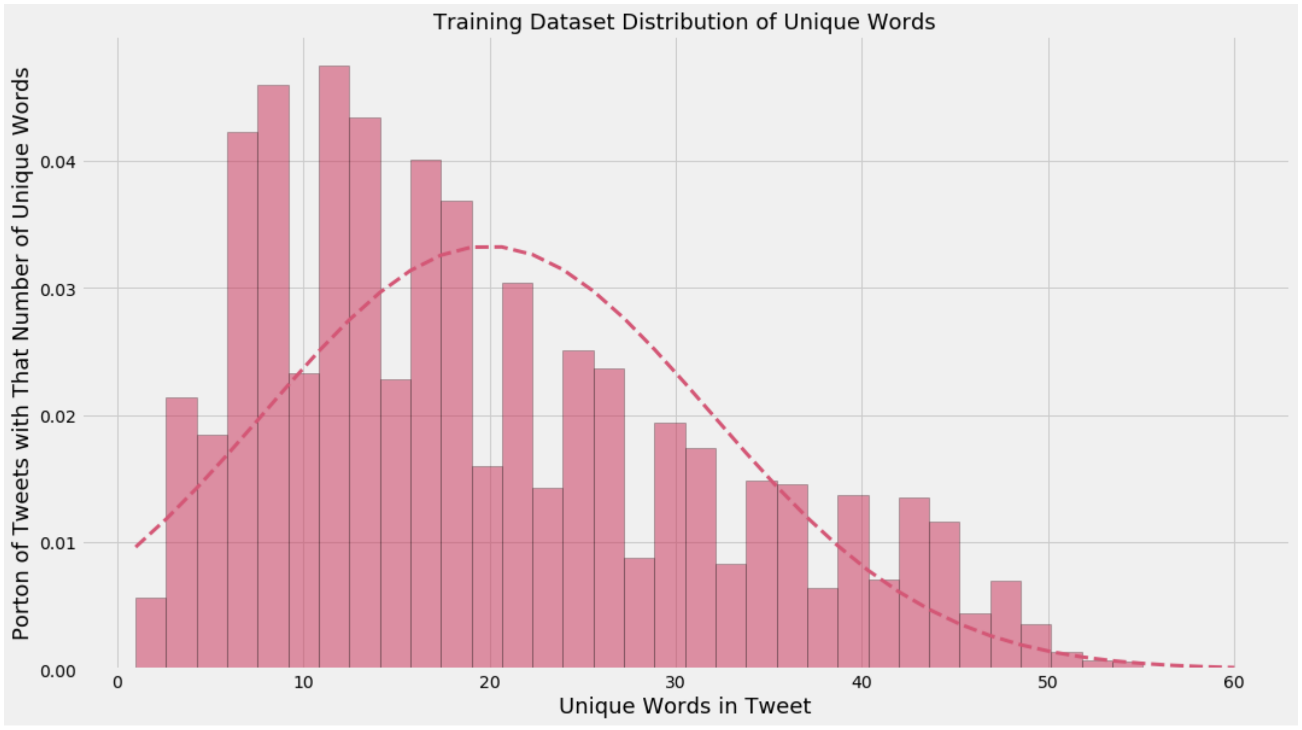
```
punctuation_mean = punctuation_data_for_stats.describe().Punctuation[1]
punctuation_std = punctuation_data_for_stats.describe().Punctuation[2]

fig = plt.figure(figsize=(16, 9))
ax = fig.add_subplot(111)

n, bins, patches = ax.hist(punctuation_data,
                           bins="scott",
                           edgecolor="black",
                           density=True,
                           color="#420039",
                           alpha=0.5)

punctution_line = scipy.stats.norm.pdf(bins, punctuation_mean, punctuation_std)
ax.plot(bins, punctution_line, "--", linewidth=3, color="#673260")

ax.set_title("Training Dataset Distribution of Punctuation", fontsize=18)
ax.set_xlabel("Punctuating Characters", fontsize=18)
ax.set_ylabel("Porton of Punctuating Characters", fontsize=18)

plt.show()
```



```
stop_words_mean = stop_words_data_for_stats.describe()["Stop words"][1]
stop_words_std = stop_words_data_for_stats.describe()["Stop words"][2]

fig = plt.figure(figsize=(16, 9))
ax = fig.add_subplot(111)

n, bins, patches = ax.hist(stop_words_data,
                           bins="scott",
                           edgecolor="black",
                           density=True,
                           color="#698f3f",
                           alpha=0.5)

stop_words_line = scipy.stats.norm.pdf(bins, stop_words_mean, stop_words_std)
ax.plot(bins, stop_words_line, "--", linewidth=3, color="#87a565")

ax.set_title("Training Dataset Distribution of Stop Words", fontsize=18)
ax.set_xlabel("Stop Words in Tweet", fontsize=18)
ax.set_ylabel("Porton of Tweets with That Number of Stop Words", fontsize=18)

plt.show()
```



```
unique_words_mean = unique_words_data_for_stats.describe()["Unique words"][1]
unique_words_std = unique_words_data_for_stats.describe()["Unique words"][2]

fig = plt.figure(figsize=(16, 9))
ax = fig.add_subplot(111)

n, bins, patches = ax.hist(unique_words_data,
                           bins="scott",
                           edgecolor="black",
                           density=True,
                           color="#Ca2e55",
                           alpha=0.5)

unique_words_line = scipy.stats.norm.pdf(bins, unique_words_mean, unique_words_std)
ax.plot(bins, unique_words_line, "--", linewidth=3, color="#d45776")

ax.set_title("Training Dataset Distribution of Unique Words", fontsize=18)
ax.set_xlabel("Unique Words in Tweet", fontsize=18)
ax.set_ylabel("Porton of Tweets with That Number of Unique Words", fontsize=18)

plt.show()
```


Training Dataset Distribution of Unique Words
Porton of Tweets with That Number of Unique Words
Unique Words in Tweet
0.00
0.01
0.02
0.03
0.04
0
10
20
30
40
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