A Sentiment Analysis of COVID-19 Tweets and its effects on Likeability and Retweet-ability.

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# Introduction

Social media has expanded tremendously in the past decade. It is common for government officials to use Twitter to relay public messages and announcements (Ontario Government, 2020), and also for individual users to rely on Twitter as their primary source of news (Glenski, et al., 2018). In the past, social media platforms has chosen a laissez-faire approach when dealing with user-generated messages (Caplan, 2017), however with a traffic of 500 millions tweets posted on Twitter per day (Pereira-Kohatsu, et al., 2019) where majority are posted by individuals users (Oren, et al., 2020), Twitter has slowly become a breeding ground for rumours and misinformation (Shao, et al., 2018); an ongoing issue social media platforms struggle to find a balance to address (Culliford, 2020).

As we step into 2020, the COVID-19 pandemic fills our everyday news while causing disturbance to all levels of society across the global (Hinshaw, 2020). Due to the novelty of the virus, governments and health officials often struggle to form straightforward and coherent guidelines and policies due to discovery of new information (Farzan, et al., 2020). This can contribute to public mistrust on the health authorities; indirectly fanning the spread of rumours and misinformation (Kouzy, et al., 2020). In turn, it hinders the effectiveness of public health policies when people feed on misinformation (Bode & Vraga, 2017) as studies have shown misinformation are spread and consumed by like-minded people; ricocheting like an echo chamber (Vicarioa, et al., 2016).

Monitoring the vast amounts of social media messages have become humanly impractical, therefore research into using machine learning and data analytic techniques to tackle the problem has become a popular research topic in recent years, and many papers have described partial or complete solutions with different degrees of success. In our capstone project, we will attempt to implement a small part of a big puzzle; create a new feature using sentiment analysis tools to score each tweet, and then build regression models to predict whether sentiment score, along with other features, contribute to retweets or likes. This will allow us to better understand whether a tweet’s sentimentality can influence how it resonates with other people.

# Literature Review

Here is the literature review of some academic papers describing challenges when conducting Natural Language Processing on social media message since they come in different formats compare to traditional literature.

**Twitter rumour detection in the health domain**

Sicilia et al. in “Twitter rumour detection in the health domain” (Sicilia, et al., 2018, pp. 34-35) described the construction of a complete detection system that can distinguish rumour or non-rumour tweets on topics related to the health sector. Rumours are defined as information from an unverified source, non-rumours are information that can be referenced to credible sources and official pages, and unknown are information that cannot be verified has either true or false (Sicilia, et al., 2018, p. 35). Data downloaded from Twitter, separated based on user or network level, feature selected based on performance, and finally trained into classification model (Sicilia, et al., 2018, pp. 35-36). The author used various machine learning techniques such as Support Vector Machine, Nearest Neighbour, and Random Forest and compared the results based on their averaged accuracies and compared their -values (Sicilia, et al., 2018, pp. 38-39). The study was able to achieve an over accuracy of 74%, precision of 73%, and recall of 74% (Sicilia, et al., 2018, p. 39).

Ravi in “A survey on opinion mining and sentiment analysis: Tasks, approaches and applications” conducted a comprehensive review and experimented on different sentiment analysis techniques described in over 300 papers on six tasks, namely: subjectivity classification, sentiment classification, review usefulness measurement, lexicon creation, opinion spam detection, and aspect extraction” (Ravi, 2015, pp. 4-5). The study compared dozens of different sentiment analysis approaches and techniques with various degree of success on certain machine learning techniques when compared to vote count based measures (Ravi, 2015, pp. 55-57). Ravi concluded that there is still room for growth on intelligence-based techniques such as Random Forest (Ravi, 2015, p. 64).

Carlos et al. in “Detecting and Monitoring Hate Speech in Twitter” describes social media platforms dominate much of the internet, and with hundreds of millions of messages being conveyed through these platforms, hate messages begin to spread in wide varieties of subjects (Pereira-Kohatsu, et al., 2019, p. 2). The paper describes a system where it takes an input as text and emoji to help identifying and classifying hate speech in Twitter, and monitoring negative sentiments (Pereira-Kohatsu, et al., 2019, pp. 1-2). After experimenting with 19 different strategies of feature and classification models, the authors concluded with a model that combines LSTM and MLP-NN achieving AUC OF 0.828 (Pereira-Kohatsu, et al., 2019, p. 31).

Social media platforms currently are mostly unmoderated; allowing rumours or unverified information can easily spread and circulate on the platform (Zubiaga, et al., 2018, p. 32:1). Zubiaga et al. in “Detection and Resolution of Rumours in Social Media: A Survey” describes combining different various techniques in rumour detection, tracking, stance classification, and veracity classification together to form a rumour detection system that will provide users with early warning of messages containing uncertain information (Zubiaga, et al., 2018, pp. 32:1-32:2).

Sewalk et al. in “Using Twitter to Examine Web-Based Patient Experience Sentiments in the United States: Longitudinal Study” starts with the premise there is a shift to focusing more on patient experience and emotion, increasing transparency and patient engagement in health care (Sewalk, et al., 2018, p. 2). As Twitter has become a primary platform for people to voice their opinions, the authors conducted sentiment analysis on tweets based on patient tweets, such as wait time, as a method to evaluate their treatment experiences (Sewalk, et al., 2018, pp. 10-11).

# Dataset

For this project, we will use a dataset of Tweets filtered with 90+ COVID-19 related keywords and hashtags ([link](https://rlamsal.com.np/keywords.tsv)), publicly available from IEEE DataPort (<https://ieee-dataport.org/open-access/coronavirus-covid-19-tweets-dataset>). This dataset contains only tweets IDs and must be covered to Tweets using a Hydrator program. The resulting hydrated CSV have 34 attributes: coordinates, created\_at, hashtags, media, urls, favorite\_count, id, in\_reply\_to\_screen\_name, in\_reply\_to\_status\_id, in\_reply\_to\_user\_id, lang, place, possibly\_sensitive, retweet\_count, retweet\_id, retweet\_screen\_name, source, text, tweet\_url, user\_created\_at, user\_screen\_name, user\_default\_profile\_image, user\_description, user\_favourites\_count, user\_followers\_count, user\_friends\_count, user\_listed\_count, user\_location, user\_name, user\_screen\_name, user\_statuses\_count, user\_time\_zone, user\_urls, user\_verified.

For our project, the features selected are as follows:

Table 1 List of attributes used in this project.

|  |  |
| --- | --- |
| Feature | Description |
| favorite\_count | No. of “liked” this tweet has |
| retweet\_count | No. of retweet this tweet has |
| user\_followers\_count | No. of follower Tweet’s account has |
| user\_statuses\_count | No. of tweets and retweets this user issued |
| user\_favourites\_count | No. of tweets this user liked |
| user\_followers\_count | No. of followers this account has |
| user\_friends\_count | No. of users this account follows |
| user\_listed\_count | No. of public lists this user is a member of |
| Compound | New feature: sentiment score calculated by sentimental analyzing tool with values between -1 negative and +1 positive. |

# Approach

Figure 1 shoes a sequential approach to our capstone project. The steps should align with the code outlined in Jupyter notebook.

Figure 1 Project approach diagram

## Step 1: (Pre-Python) Download and Prepare Dataset

IEEE.org Coronavirus Tweet Dataset (<https://ieee-dataport.org/open-access/coronavirus-covid-19-tweets-dataset>) contains a list of individual datasets broken by their date since March 2020. Note that the project can accommodate multiple dates depending on computational power available. The CSV file contains only two features: Tweet ID and sentiment score. Since our task is to conduct our own sentiment analysis on the tweets, we will discard the sentiment score and preserving only Tweet ID. Open the CSV file with any CSV editor of your choice, such as Excel, and remove the sentiment score (2nd attribute) from the CSV. There should only be one attribute with one tweet ID per row. Save this file as .txt and close the file.

## Step 2: (Pre-Python) Hydrate dataset

Since the .txt file contains only the tweet IDs, the tweet IDs will need to be converted into Tweets. This process involves loading the tweet ID to a Hydrator program which will sequentially pull Tweets using Twitter’s API and following are the procedures.

Download Hydrator from <https://github.com/DocNow/hydrator>, then follow the installation procedures, and open the Hydrator program after installation is complete. In the Hydrator program, click "Setting" tab on the top, and follow the instructions to link the program to your Twitter account. This provides permission for the Hydrator program to read Tweets using the Tweet IDs. Then, switch to the “Add" tab, click "Select Tweet ID file" and select the previously created .txt file filled with tweet IDs. Under "Title" field, give the dataset any name, then click "Add Dataset" button and the program will switch to the “Dataset” tab. Click the “Start” button for the hydration process to begin. Note that this will take an extended amount of time, as there is a limit to how many tweets, as per Twitter API Rate Limits, a Twitter Account can retrieve in a certain timeframe. Once the hydration process is complete, click "CSV" button and a dialog box will pop up asking for a CSV filename you wish to save the results to; give any descriptive filename. Note that the file size will be quite large. Load this CSV file onto a cloud storage service—we used Google Drive for this project.

## Step 3: (Python) Preload Setup

On Jupyter (Colab) notebook, preload basic parameters such as display tables in full screen widths, increasing number of columns displayed, or other settings to improve productivity while working on the notebook.

## Step 4: Import Dataset in Pandas Dataframe

We need to give Colab access to the CSV file previously stored in Google Drive. First, mount Google Drive onto the Colab project by loading the Google Colab library, then run and follow instructions (see Figure 2). Google will ask whether to grant permissions to Colab, and upon acceptance it will return with an authorization code.

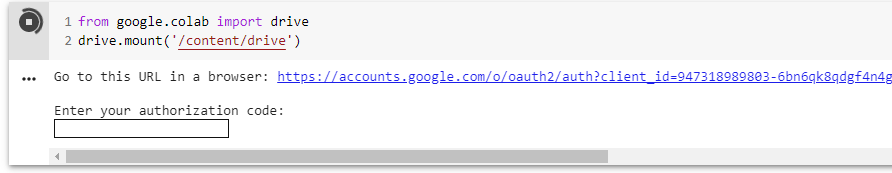


Figure 2 Instructions to follow the link to get authorization code

Copy and paste the authorization code back to Colab notebook into the provided text box. If the code is valid, a message will appear “Mounted at” (see Figure 3) which indicates the authorization is successful and Colab is given read privileges to the CSV file in Google Drive. Once Colab can read the dataset, use read\_csv to load and store the CSV file in Pandas dataframe.

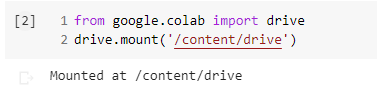


Figure 3 Status should "Mounted" after successfully pasting a valid authorization key.

## Step 5: Perform Data Cleaning

Take a moment to observe and understand the data’s structure and composition, then perform data cleaning such as handle of null values, convert attribute data types, and remove noise from strings. For more detailed understanding of Twitter’s data structure, visit Data dictionary reference at <https://developer.twitter.com/en/docs/twitter-api/v1/data-dictionary/overview/user-object>. Notice that the feature labels in our CSV might be longer; appear to have extra prefixes, and this is because the raw data retrieved from Twitter API is in multi-dimensional JSON format, which has to be flatten to two dimension by adding extra prefixes, before it can be stored as CSV.

Since retweets are duplicates of the original tweet, we only need to focus on original tweets. Therefore, we filter the dataset to only include Original Tweets and save them into a new dataframe.

The sentiment analyze algorithm works best on English text, and tweets that are not written in English waste processing resources and can affect our results. Using langdetect library, we parse each tweet and exclude any data points containing complete or partial non-English tweets. This process will take some time to complete.

## Step 6: Sentiment Analysis

From NLTK library, import SentimentIntensityAnalyzer and apply the polarity\_scores function onto each tweet in the Original Tweet dataframe. The function returns a dictionary object: probability of negative, probability of neutral, probability of positive, and normalized compound score. We can expand the dictionary object using their key as feature and value as datapoint into 4 new features and merge the new features back to the dataframe for easier analysis.

The “compound” score is calculated from raw sentiment intensity and not derived from negative, neutral, and positive probabilities. It scores between -1.00 and +1.00 and provides us with a single dimension sentiment score which is easier to work with.

## Step 7: Basic Analysis

After all preparations are ready, we can conduct some basic analysis with the 9 features, such as: correlation, mean, standard deviation, and their quartiles.

Using the “compound” score, we can plot a histogram based on frequency and observe its distribution. By categorizing each tweet using the compound score as: negative between -1 to 0.1, neutral between -0.1 to +0.1, and positive between 0.1 to 1, we can plot a pie chart to show the ratio between each category.

## Step 8: Build Prediction Model for “Favourite Count” with Linear Regression

Of the 9 features, we use “favorite\_count” as dependent variable, and the rest as independent variable. Sample 80% of the dataset into train set, and 20% into test set. Using sklearn library, linear\_model class, LinearRegression() method, load the dependent and independent variables from the train set into LinearRegression(), and then using the independent variable from the test set to predict the dependent variable. Then compare the predicted dependent variable with the actual dependent variable from test set to obtain some metrics on the fit of the model, such as MSE, RMSE, MAE, , and adjusted .

Next, plot a scatterplot using the predicted dependent variable as y-axis, and actual dependent variable from test set as x-axis will give us a visualization of how well the prediction versus actual values are. If outlying values “stretch out” the graph hindering visualization, we can apply a technique to limit the scatterplot to show prediction only within 3-sigma, or 2-sigma range.

## Step 9: Build Prediction Model for “Retweet Count” with Linear Regression

Build another linear regression model just like Step 8, but substitute “retweet\_count” as dependent variable.

## Step 10: Linear Regression with k-fold

In Step 8 and 9, the linear regression was built using only one sample of the dataset. Step 10 will modify and replace the sampling to *k*-fold cross-validation.

From sklearn.mode\_selection, import KFold. Initialize some variables used to accumulate MSE, RMSE, and scores. Initialize KFold and specify the number of folds, load the KFold split onto a variable. Then create a for loop to iterate through this variable, and within each iteration run LinearRegression()—same as Step 8 for “favorite\_count” as dependent variable. After iteration is done, take the accumulated MSE, RMSE, and and divide by the number of KFold to get the average score respectively. Print the average MSE, RMSE, and scores.

Repeat Step 10 again but substitute “retweet\_count” as dependent variable—just like Step 9.

## Step 11: Build Polynomial Regression

Here we will use polynomial regression on a single sampling (just like Step 8) to see whether we can build a better model than linear regression. First from sklearn.pipeline, import make\_pipeline, and from sklearn.preprocessing import PolynomialFeatures. Specify the number of degrees to iterate through. The degrees is the number of terms in a polynomial equation, and more terms adds complexity which requires more computation power and memory—we used 1, 2, 3, and 6 for our model. Just like in Step 8, sample 80% of the dataset to train set and remainder 20% to the test set. Create an iteration by degrees, and for each degree, use make\_pipeline to load the dependent and independent train set, along with the number of degrees into the polynomial regression. Then we load independent from the test set and store the predicted values in a multi-dimensional numpy.array.

To create a scatterplot using matplotlib, iterate through each row in the array, cycling different colour for each column will result to a plot showing different colour dot for each degree prediction (see example Figure 21 Polynomial regression with favorite\_count as dependent variable).

Next, get the score by iterating the array again and use r2\_score(Y\_test, Y\_predicted) to generated the score (see Figure 4).



Figure 4 score for polynomial regression

## Step 12: Build Polynomial Regression with k-Fold

For Polynomial Regression with k-Fold, follow Step 10 and iterate each fold following Step 11. Note that the variables used to accumulate MSE, RMSE, and score will need to change to multi-dimensional since there are extra dimensions for polynomial regression—degrees.

Complete this step for both dependent variables: favorite\_count and retweet\_count.

## Results

In this section, we will showcase some interesting observations and well as results from regression models near the end.

### Data Cleaning

Tweet text can be filled with noise which might hinder sentiment analysis algorithm. Figure 5 shows some example of Tweet text noises: \n for newline that is concatenated with ordinary English words; user referrals (@RehamKhan1) using a user’s handle name which has no sentiment meaning on its own other than referencing another user; and hashtag (#CoronaJihad) with multiple words concatenated together without spaces in between.

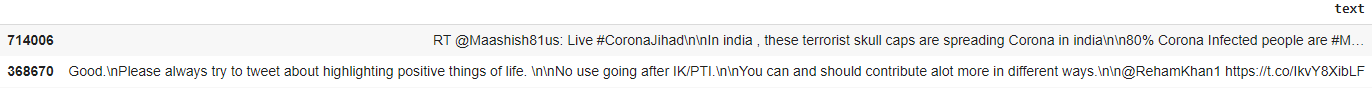


Figure 5 Example of Tweets with noise

### Observations from Tweets and Compound Score

Observing the compound score generated by the algorithm, we notice some interesting results. Figure 6 shows two tweets where the one on top has no context, and the bottom tweet has a negative sarcastic tone but the scored 0.00 for both. Figure 7 shows another example of negative sarcastic tone.

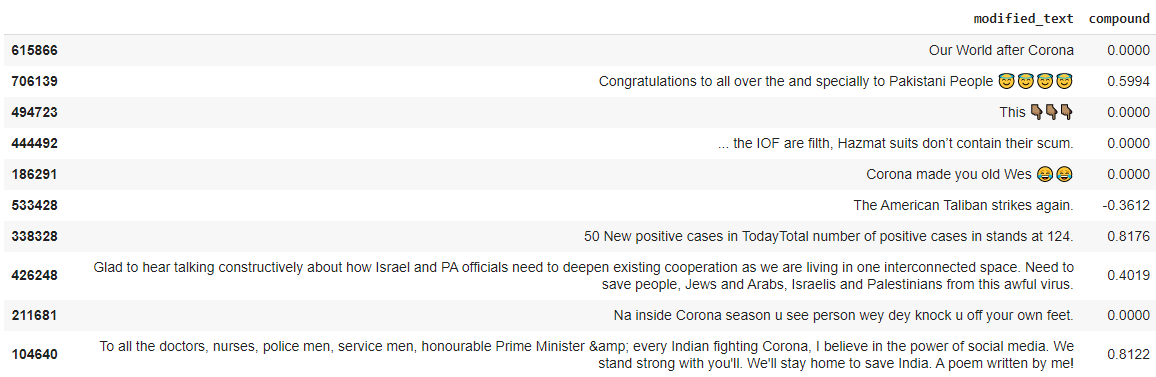


Figure 6 Tweets with sarcastic tone or without context

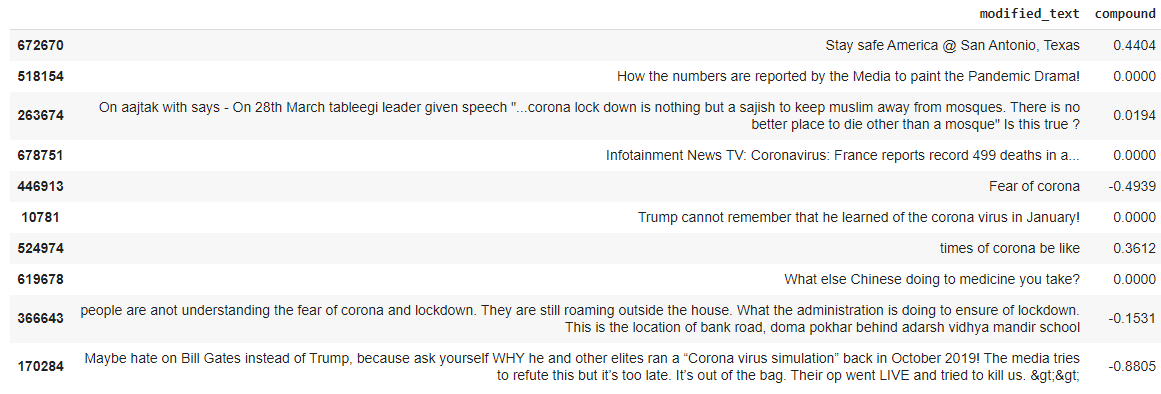


Figure 7 Tweet with sarcastic tone

Figure 8 shows a tweet that reads neutral, but has a score of 0.8176 suggests some words, such as “positive”, can incorrectly boost scores.

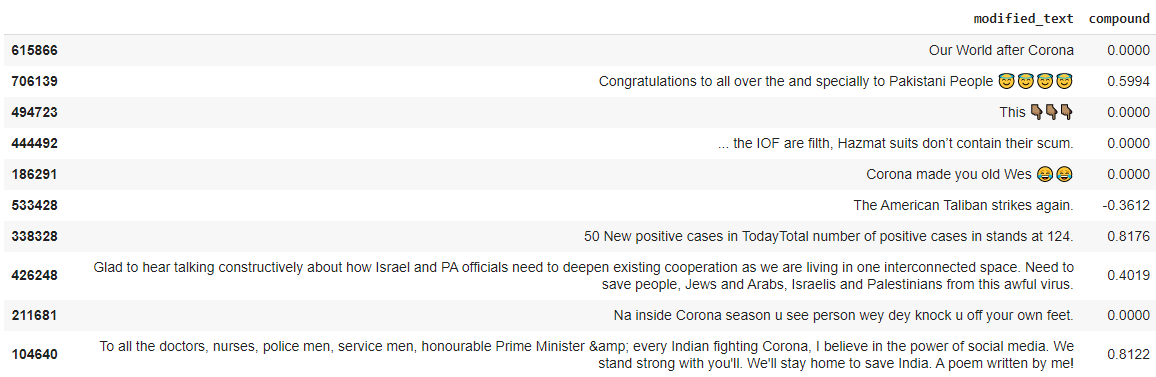


Figure 8 Tweet with "positive" word

Figure 9 and Figure 10 show tweets written in complete sentences and given a score that appears justified.

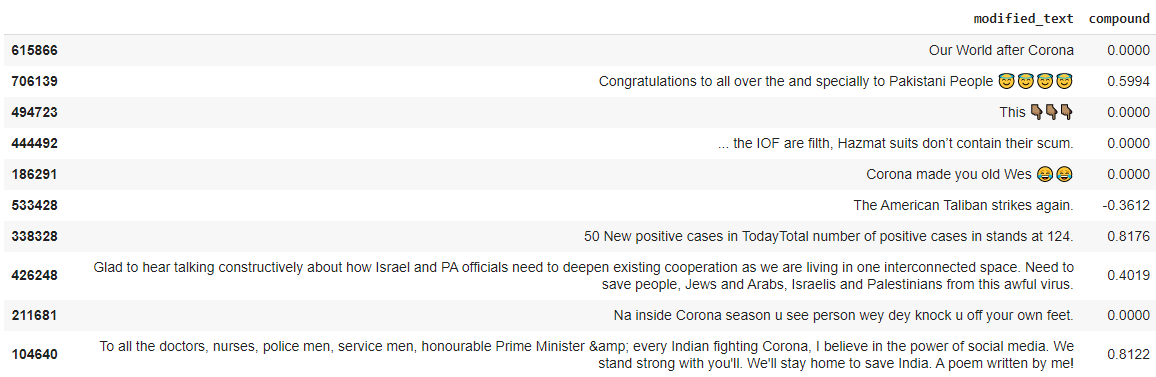


Figure 9 Tweet written in complete sentence

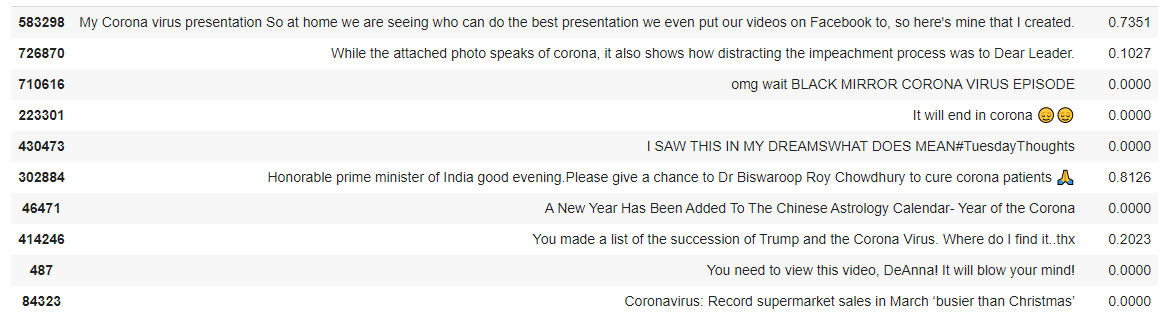


Figure 10 Another tweet written in complete sentence.

### Sentiment Score Distribution

We take the compound feature from the dataset and plot a frequency histogram (Figure 11) to observe the distribution of the sentiment score. There are a few observations based on the graph: there is an extremely high concentration of sentiment scored between 0.00 and 0.05; the two extremes at -1.00 and +1.00 ; it is multimodal. The compound score can also be grouped into 3 categories based on Deo et al.’s threshold designations: negative for compound scores between -1.00 and -0.10, neutral between -0.10 and 0.10, and positive between 0.10 to 1.00. The distribution on this categorization (see Figure 12) shows percentage of negative and positive are close, where neutral takes at most 30% due to is narrower range of thresholds.

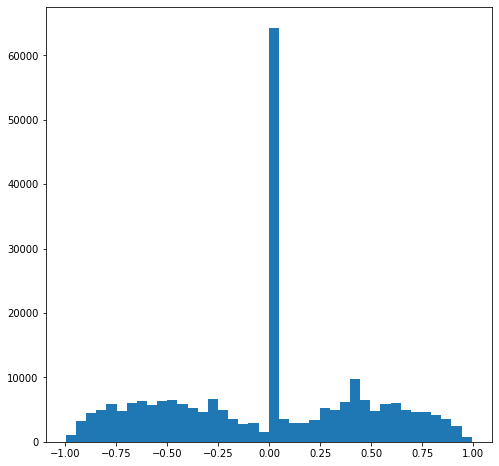


Figure 11 Histogram for Sentiment Score in 40 bins

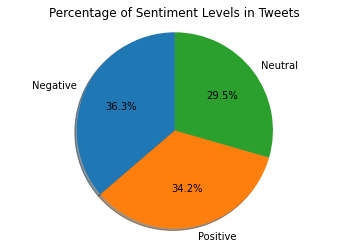


Figure 12 Percentage of Negative, Neutral and Positive Sentiment Levels in Tweets

### Basic Analysis

Figure 13 shows a table of correlation between 9 features which will be used as our dependent and independent variables for regression model. Favorite\_count (number of likes of a tweet) and retweet\_count (number of retweets of a tweet) has the highest correlation of 0.908576, and user\_followers\_count (number of followers this tweet’s account has) and user\_listed\_count (number of public lists this users is a member of) has the second highest correlation of 0.609057. The introduced feature “compound” has a very low correlation with all other features.

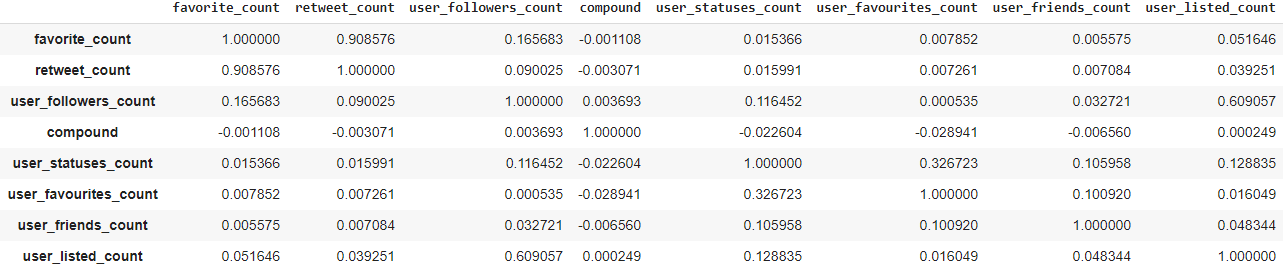


Figure 13 Correlation between 9 features

Figure 14 shows a table give us some basic statistics of each feature. The standard deviation for all features except compound is high relative to its mean, which tells us the distribution is spread out to the right.

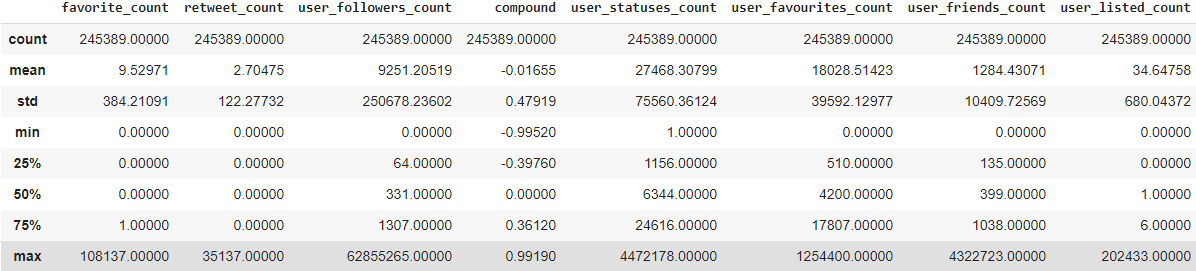


Figure 14 Describing the 9 features

### Linear Regression

#### Favorite\_count as dependent variable

Figure 15 shows a scatterplot with favorite\_count as dependent variable and the eight other features as independent variable. Observations are dense when the count is under 20, and then gradually spread to the right as the count increase. Prediction does not appear to do exceptionally well, especially when the count is under 20.

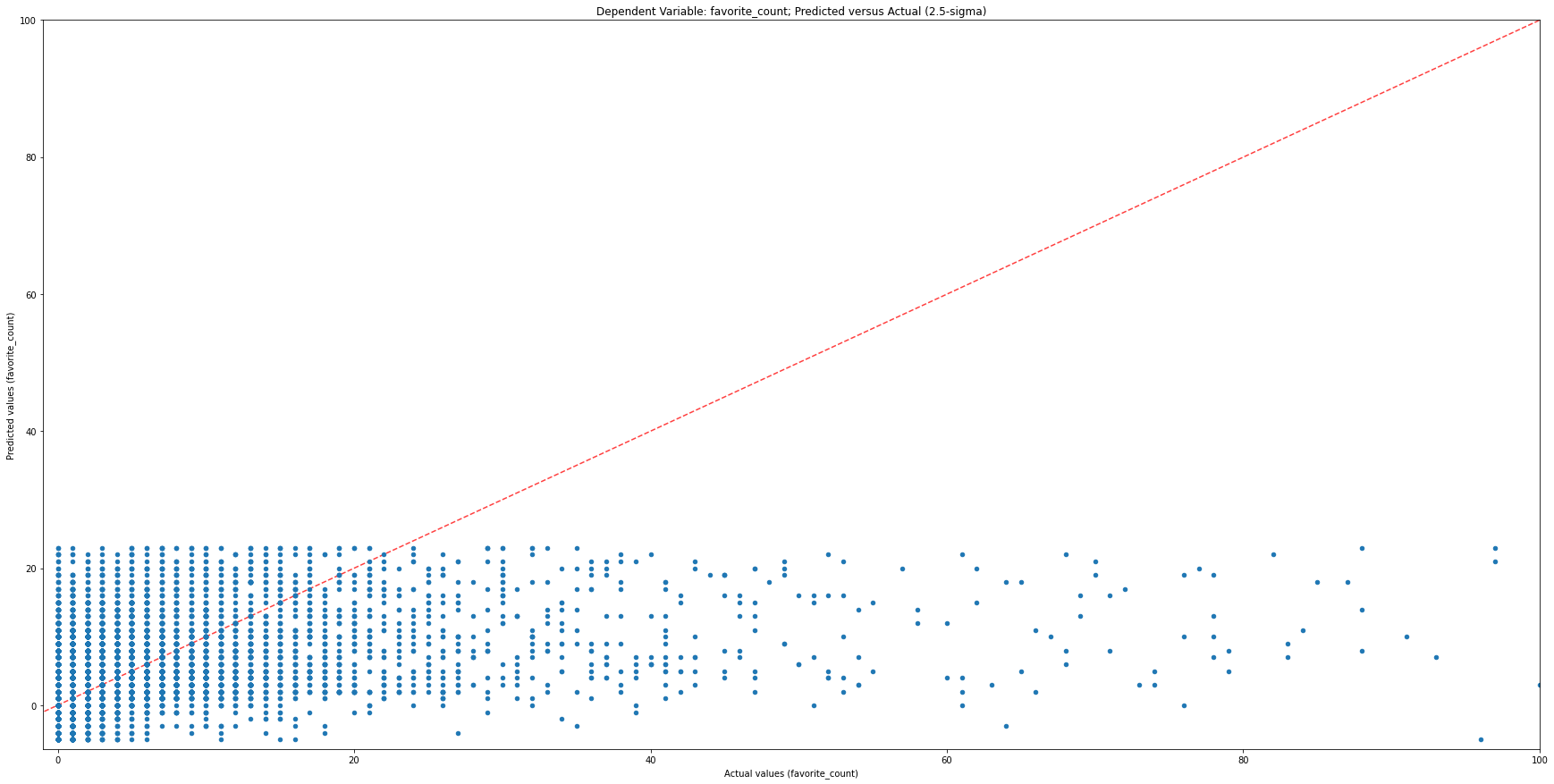


Figure 15 Scatterplot for Predicted vs Actual; favorite\_count as dependent variable; Linear Regression

The metrics from Figure 16 shows that retweet\_count and compound feature have the highest coefficient in the linear regression model. The RMSE of the model is which is high especially for lower values, however it also has an , which shows the model fits close to the regression line.

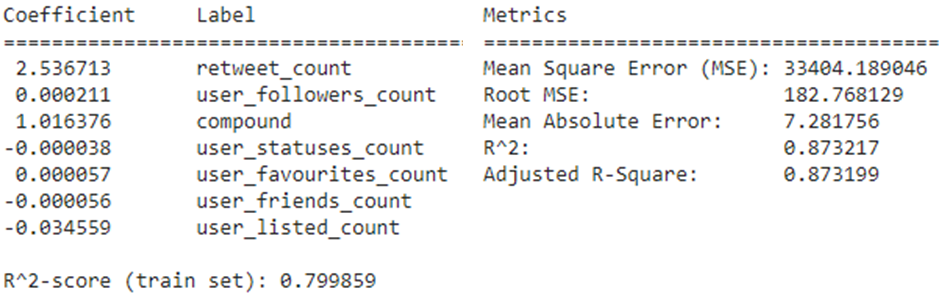


Figure 16 Metrics for Figure 15

#### retweet\_count as dependent variable

Next, we build another linear regression model with retweet\_count as dependent variable and created the scatterplot as shown in Figure 17. Similar to the previous linear regression shown in Figure 15, there is a high concentration of count under 25, and gradually disperse to the right and slightly upwards as the count increases.

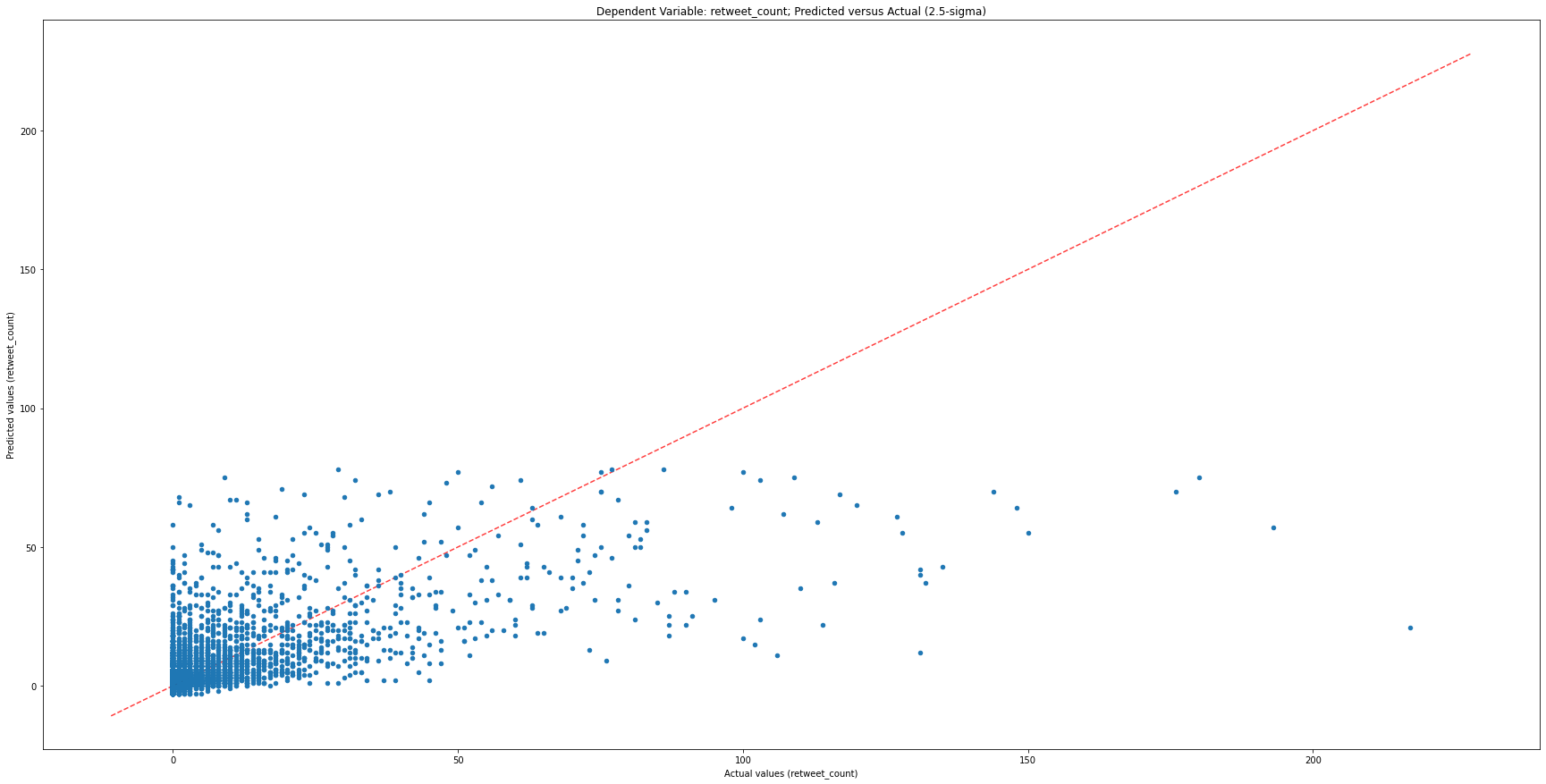


Figure 17 Scatterplot for Predicted vs Actual; retweet\_count as dependent variable; Linear Regression

The metrics for Figure 17 is shown in Figure 18 where favorite\_count and compound features have the highest coefficient in the model. The RMSE of the model is lower at and the is high.

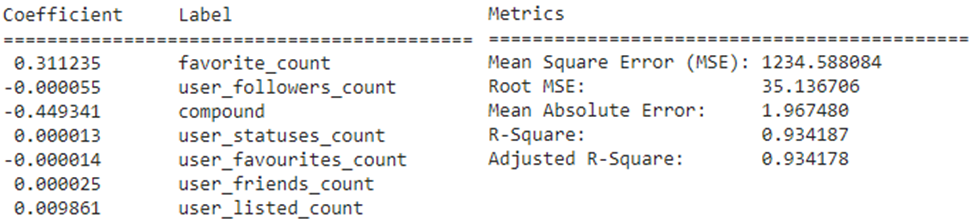


Figure 18 Metrics for Figure 17

### Linear Regression with *k*-fold

Since the previous linear regressions is conducted with only one sampling, we will use k-fold = 5 and reconduct the two linear regression models again to get a more accurate RMSE and of the models.

#### K-fold, favorite\_count as dependent variable

Figure 19 shows the RMSE to be compare to previous is a slight but not significant improvement. is compare to previous is a slight decrease.

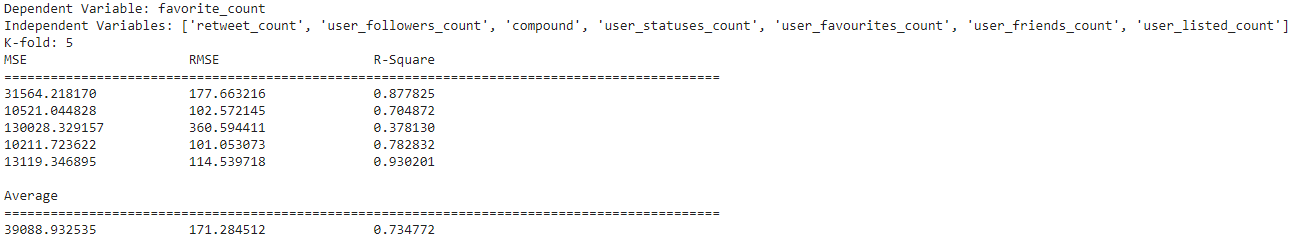


Figure 19 K-fold linear regression with favorite\_count as dependent variable

#### K-fold, retweet\_count as dependent variable

Figure 20 shows the RMSE to be compare to previous is a slight improvement. is compare to previous shows a slight decrease in average model fit.

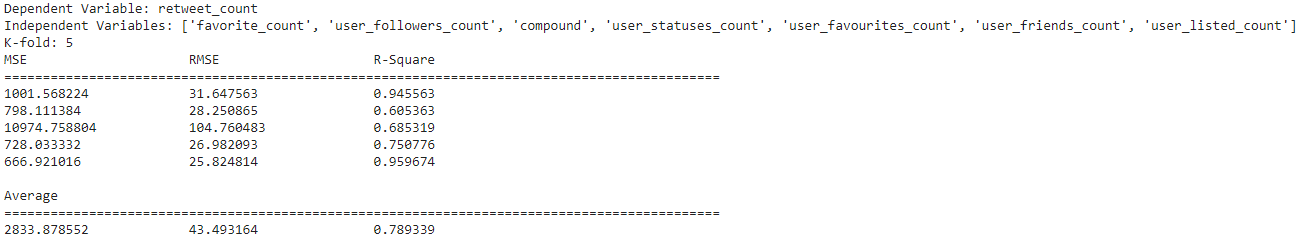


Figure 20 K-fold linear regression with retweet\_count as dependent variable

### Polynomial Regression

Next, we will attempt to produce a better model with another regression—polynomial regression. First, we create a polynomial regression for each of the two dependent variables—favorite\_count and retweet\_count using one sampling and degrees 1, 2, 3, and 6 to plot a scatterplot for visual observation. Then, we will run the models again with *k*-fold, just like previous linear regression models. Due to the increased in computation resources of polynomial regression in multi-degrees, we must lower the number of independent variables from 9 features to 5 features. Although the four features dropped have the lowest coefficients based on some previous linear regression sample, the coefficient values can change from time to time depending on the training sample—therefore it will not be the lowest coefficients in all training. Also, this adds complications when conducting comparison between linear regression and polynomial regression performances.

Figure 21 shows a polynomial regression with favorite\_count as dependent variable with four degrees. The test score is the score, which shows degree 1 and 2 have the highest scores, and degrees 3 and 4 being relatively much worse. Degree 1 has the highest score which suggests the model is just as good as linear regression.

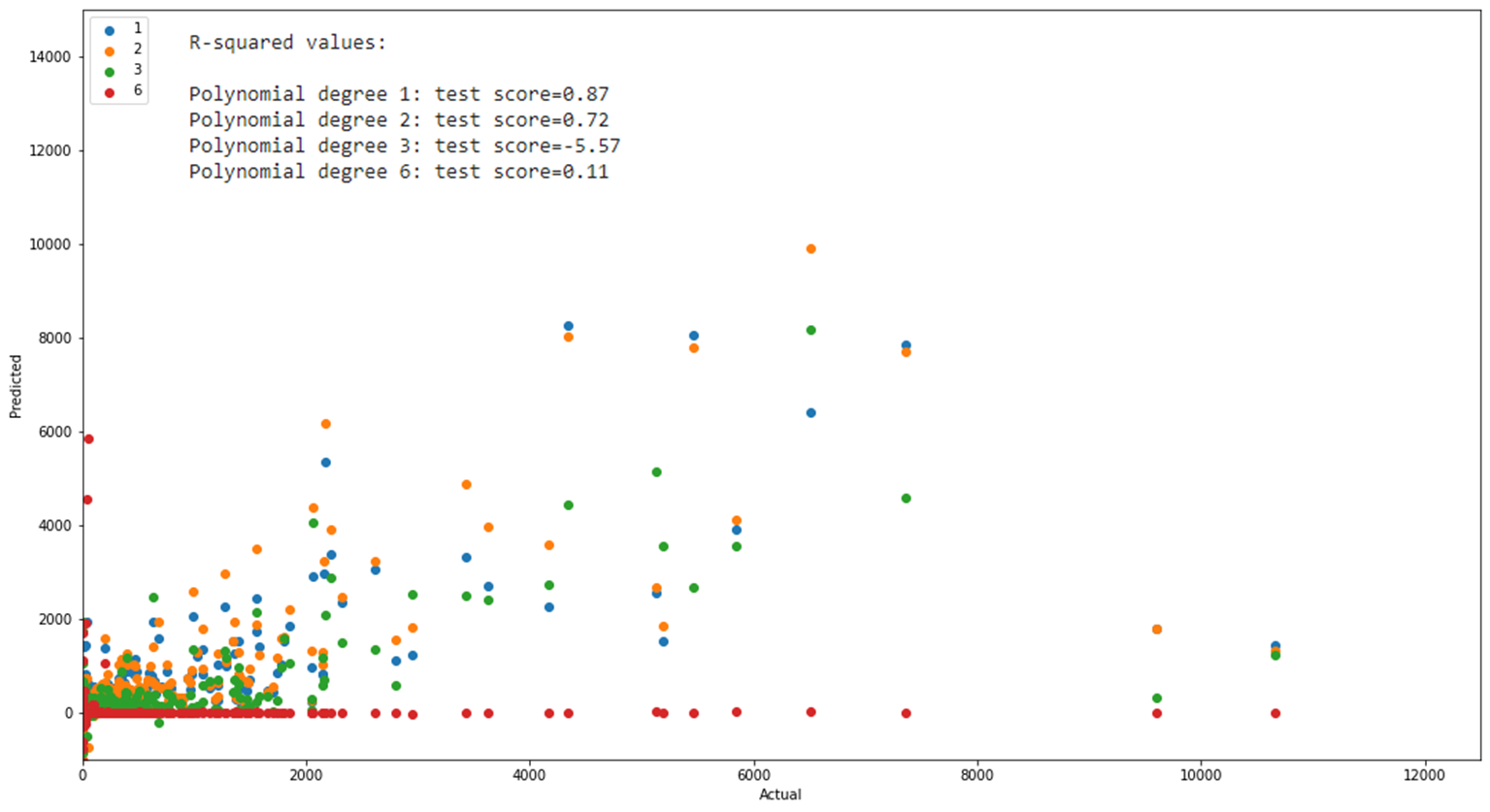


Figure 21 Polynomial regression with favorite\_count as dependent variable

Figure 22 shows another polynomial regression with retweet\_count as dependent variable. The metric shows degree 1 having the highest at , and degrees 2 and onwards fair much worse. Degree 1 being the highest score also suggests that the model is just as good as linear regression.

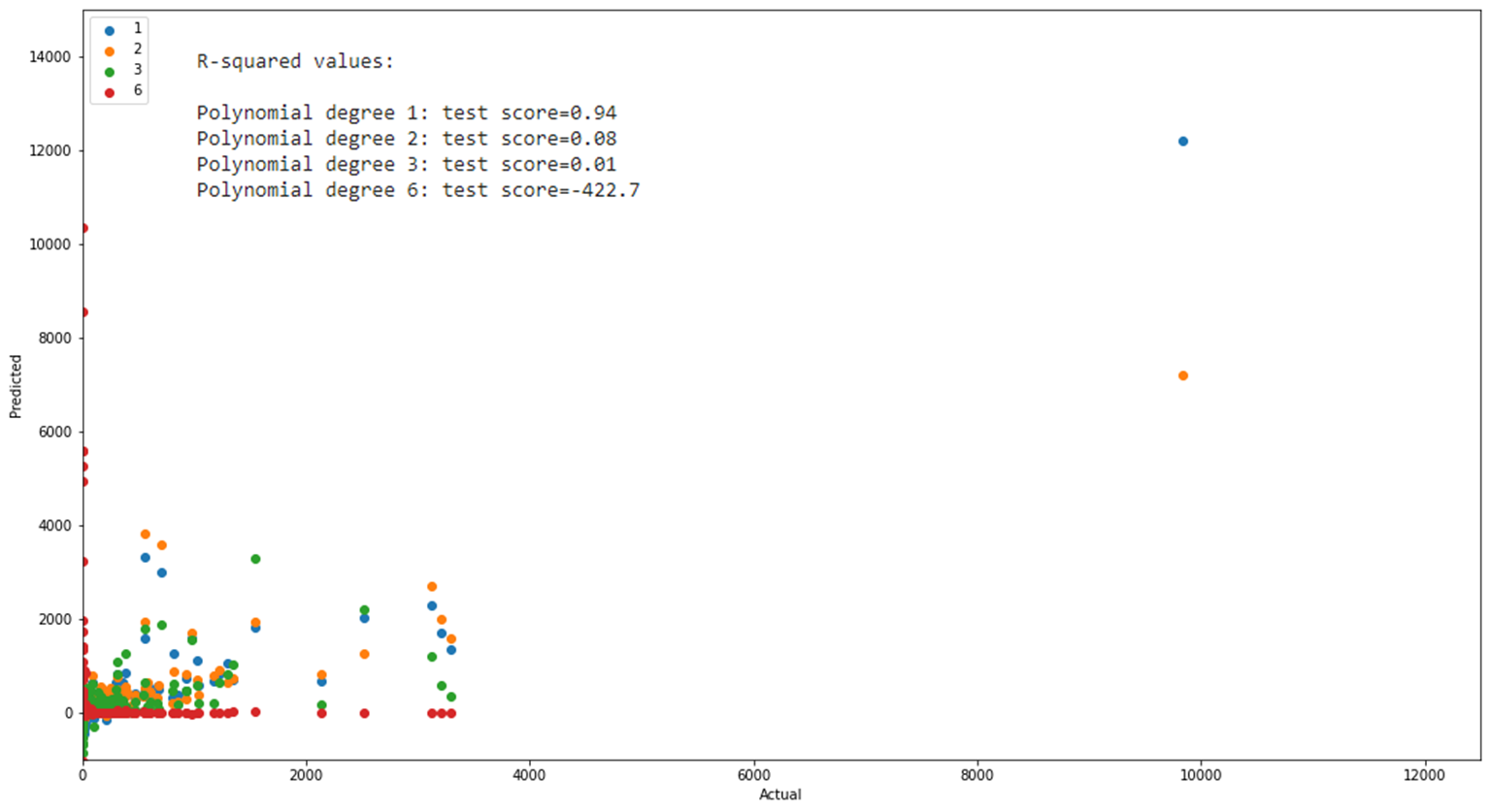


Figure 22 Polynomial regression with retweet\_count as dependent variable

### Polynomial Regression with *k*-fold

Next, we will run the same polynomial regression with *k*-fold = 5 and four degrees on the same two dependent variables respectively.

Figure 23 shows the polynomial regression with k-fold cross validation on favorite\_count as dependent variable, with an average for 1 degree; the highest of all degrees at compare to from single sampling, with an average RMSE of .

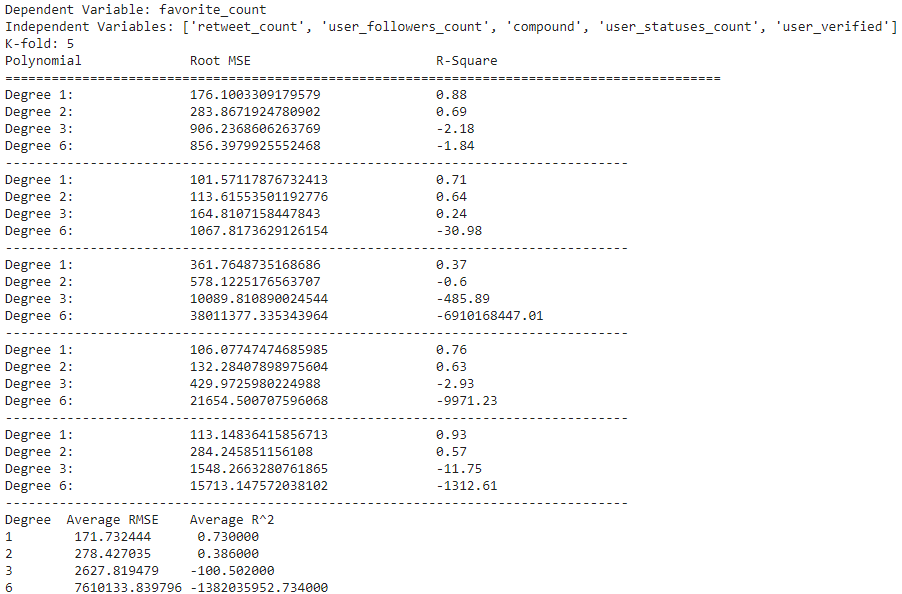


Figure 23 Polynomial Regression with k-fold and favorite\_count as dependent variable

Figure 24 shows the polynomial regression with *k*-fold cross validation on retweet\_count as dependent variable, with an average for 1 degree; again the best of all degrees at compare to from single sampling, with an average RMSE of .

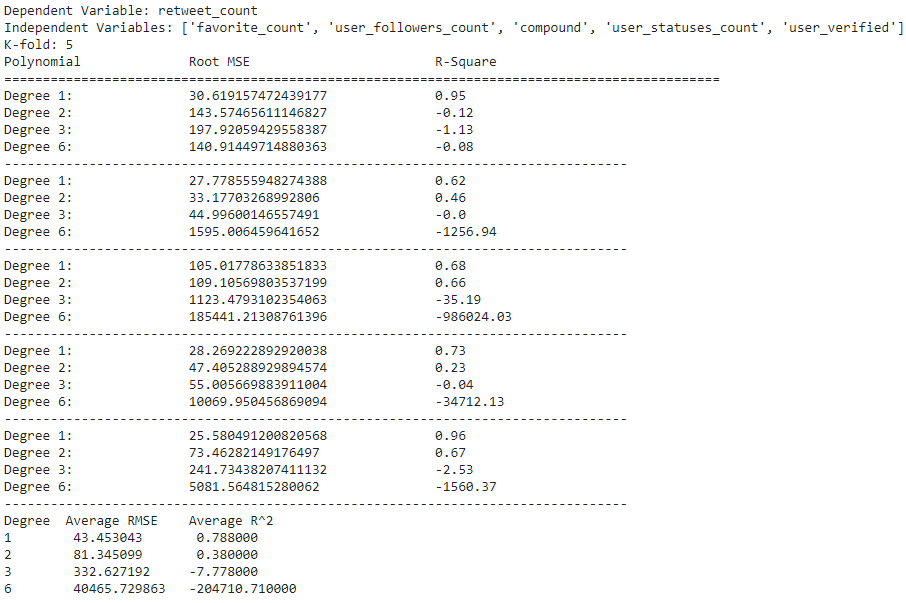


Figure 24 Polynomial Regression with k-fold and retweet\_count as dependent variable

### Comparing Results from Linear Regression with Polynomial Regression

We compare the results between Linear Regression and Polynomial Regression based on the k-fold cross validation.

Linear Regression with k-fold cross-validation where favorite\_count as dependent variable reports RMSE of and , whereas Polynomial Regression with 1-degree being the best performer reports RMSE of and . Since both results are almost identical, therefore linear regression is the preferred model as it is less complex and consumes less computation resources.

Linear Regression with k-fold cross-validation where retweet\_count as dependent variable reports RMSE of and , whereas Polynomial Regression with 1-degree being the best performer reports RMSE of and . Both results are almost identical, therefore linear regression is the preferred model.

On a side note, it should be expected that Polynomial Regression of 1-degree is essentially the same as linear regression. The metrics also tells us Polynomial Regression does not yield better fit of the model.

## Future studies and Conclusion

Future studies can consider other alternative approaches, such as: use classification instead of regression, by categorizing based on the sentiment score to provide a discrete values instead of continuous value; instead modelling regression from -1.00 to 1, consider splitting into three sentiment groups—negative, neutral, and positive and study independently as each of them might have different patterns or regression fit, such as logarithmic regression for negative and positive; group users by screen name to calculate each user’s mean sentiment score as a new feature to see whether there are any effects on number of followers and number of favourite tweets against a user’s mean sentiment score.

Our regression models were able to predict favorite\_count and retweet\_count to some extent. However, based on observations from sampling the scatterplots, there are reasonable doubts that under count of less than 20 for favorite\_count and less than 25 for retweet\_count will not yield any meaningful prediction. Favorite\_count and retweet\_count is highly correlated with each other and has the highest coefficient; significantly contribute to each other’s prediction model. Compound feature derived from the sentimentality of Tweets, although not the most prominent, is the second most significant coefficient in both regression models. Based on these reasons, we can confidently say COVID-19 Tweets’ Sentimentality does influence Likeability (favorite\_count) and Retweet-ability (retweet\_count). Although this analysis did not yield us any direct benefits, it increases our understanding on the inadequacies of sentiment analysis tools when used on social media messages. Also, we should also explore or introduce new features that might help improve our prediction models.

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