Coursera Data Science Capstone - Milestone Report

Kwasi G. Afrifa

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Synopsis

This is the Milestone Report for the John Hopkins University Coursera Data Science Capstone project.

The objective of this report is to develop an understanding of the various statistical properties of the data set that can later be used when building the prediction model for the final data product - the Shiny application. Using exploratory data analysis, this report describes the major features of the training data and then summarizes my plans for creating the predictive model.

The model will be trained using a unified document corpus compiled from the following three sources of text data:

1. Blogs
2. News
3. Twitter

The provided text data are provided in four different languages (one each in German, English, Russian, and Finnish). This project will only focus on the English corpora.

Environment Setup

Prepare the session by loading initial packages and clearing the global workspace (including hidden objects).

```r
library(knitr)
```

```
## Warning: package 'knitr' was built under R version 4.2.3
```

```r
rm(list = ls(all.names = TRUE))
setwd("C:/Users/Kwasi1/Desktop/Rcoursera")
```

Load the Data

load the training data.

```r
# blogs
blogsFileName <- "C:/Users/Kwasi1/Desktop/Rcoursera/Coursera-SwiftKey/final/en_US/en_US.blogs.txt"
con <- file(blogsFileName, open = "r")
blogs <- readLines(con, encoding = "UTF-8", skipNul = TRUE)
close(con)
```

Table 1:

File	FileSize	Lines	Characters	Words	WPL.Min	WPL.Mean	WPL.Max
en_US.blogs.txt	200 MB	899288	206824505	37570839	0	42	6726
en_US.news.txt	196 MB	77259	15639408	2651432	1	35	1123
en_US.twitter.txt	159 MB	2360148	162096241	30451170	1	13	47

```r
# news
newsFileName <- "C:/Users/Kwasi1/Desktop/Rcoursera/Coursera-SwiftKey/final/en_US/en_US.news.txt"
con <- file(newsFileName, open = "r")
news <- readLines(con, encoding = "UTF-8", skipNul = TRUE)
```

```
## Warning in readLines(con, encoding = "UTF-8", skipNul = TRUE): incomplete final
## line found on
## 'C:/Users/Kwasi1/Desktop/Rcoursera/Coursera-SwiftKey/final/en_US/en_US.news.txt'
```

```r
close(con)

# twitter
twitterFileName <- "C:/Users/Kwasi1/Desktop/Rcoursera/Coursera-SwiftKey/final/en_US/en_US.twitter.txt"
con <- file(twitterFileName, open = "r")
twitter <- readLines(con, encoding = "UTF-8", skipNul = TRUE)
close(con)

rm(con)
```

Basic Data Summary

Prior to building the unified document corpus and cleaning the data, a basic summary of the three text corpora is being provided which includes file sizes, number of lines, number of characters, and number of words for each source file. Also included are basic statistics on the number of words per line (min, mean, and max).

Initial Data Summary

```
## Warning: package 'kableExtra' was built under R version 4.2.3
```

```
## Warning in !is.null(rmarkdown::metadata$output) && rmarkdown::metadata$output
## %in% : 'length(x) = 2 > 1' in coercion to 'logical(1)'
```

> The source code for the above table is attached as A.1 Basic Data Summary in the Appendix section.

An initial investigation of the data shows that on average, each text corpora has a relatively low number of words per line. Blogs tend to have more words per line, followed by news and then twitter which has the least words per line. The lower number of words per line for the Twitter data is expected given that a tweet is limited to a certain number of characters. Even when Twitter doubled its character count from 140 to 280 characters in 2017, research shows that only 1% of tweets hit the 280-character limit, and only 12% of tweets are longer than 140 characters. Perhaps after so many years, users were simply trained to the 140-character limit.

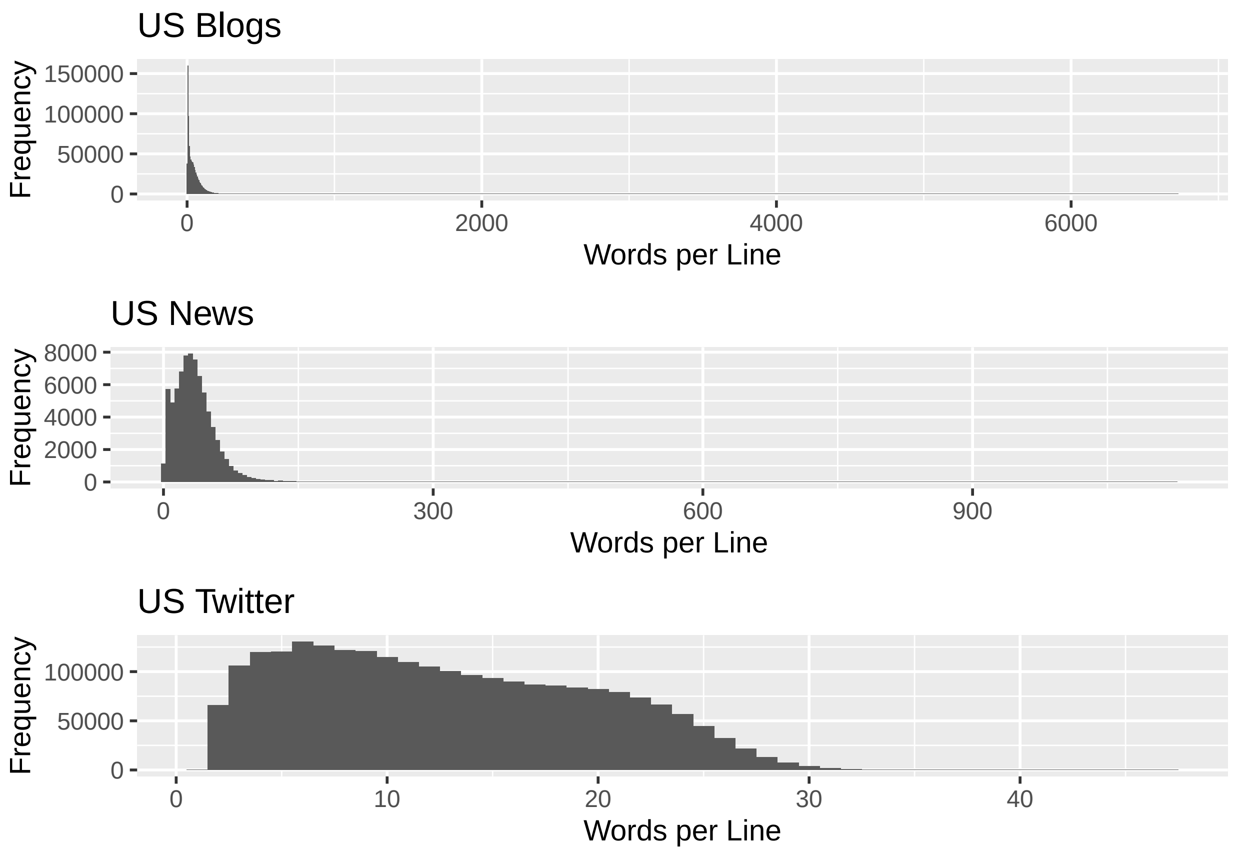
Another important observation in this initial investigation shows that the text files are fairly large. To improve processing time, a sample size of 1% will be obtained from all three data sets and then combined into a unified document corpus for subsequent analyses later in this report as part of preparing the data.

Histogram of Words per Line

```
## Warning: package 'ggplot2' was built under R version 4.2.3
```

```
## Warning: package 'gridExtra' was built under R version 4.2.3
```

```
## Warning: `qplot()` was deprecated in ggplot2 3.4.0.
## This warning is displayed once every 8 hours.
## Call `lifecycle::last_lifecycle_warnings()` to see where this warning was
## generated.
```



The relatively low number of words in the three source files charted earlier in this section is also visible in the histogram plots shown above. This observation seems to support a general trend towards short and concise communications that may be useful later in the project.

> The source code for the above plot is attached as A.2 Histogram of Words per Line in the Appendix section.

Table 2: First 10 Documents

found deryl back february can imagine shock completely devastated day called sister told going told knew bad looked like
today visited high school evening give talk library tomorrow visit another school go hamburg another appearance friday ge
captains commanders majestys fleet wear uniforms pattern
book bamako current home although field research conducted book brazzaville congo although field research conducted fac
mel asked us dress s fun time putting outfits together
g whole eggs
next meet katherine employee local mega whose delinquent brother caleb gone missing caleb played corey feldman essentia
make iconic
stereo iphone ipod laptop
never believe publishers know anything creative writing writing books

Prepare the Data

Prior to performing exploratory data analysis, the three data sets will be sampled at 1% to improve performance. All non-English characters will be removed from the subset of data and then combined into a single data set. The combined sample data set will be written to disk which contains 33,365 lines and 705,966 words.

The next step is to create a corpus from the sampled data set. A custom function named `buildCorpus` will be employed to perform the following transformation steps for each document:

1. Remove URL, Twitter handles and email patterns by converting them to spaces using a custom content transformer
2. Convert all words to lowercase
3. Remove common English stop words
4. Remove punctuation marks
5. Remove numbers
6. Trim whitespace
7. Remove profanity
8. Convert to plain text documents

The corpus will then be written to disk in two formats: a serialized R object in RDS format and as a text file. Finally, the first 10 documents (lines) from the corpus will be displayed.

```
## Warning: package 'tm' was built under R version 4.2.3
```

> The source code for preparing the data is attached as A.3 Sample and Clean the Data and A.4 Build Corpus in the Appendix section.

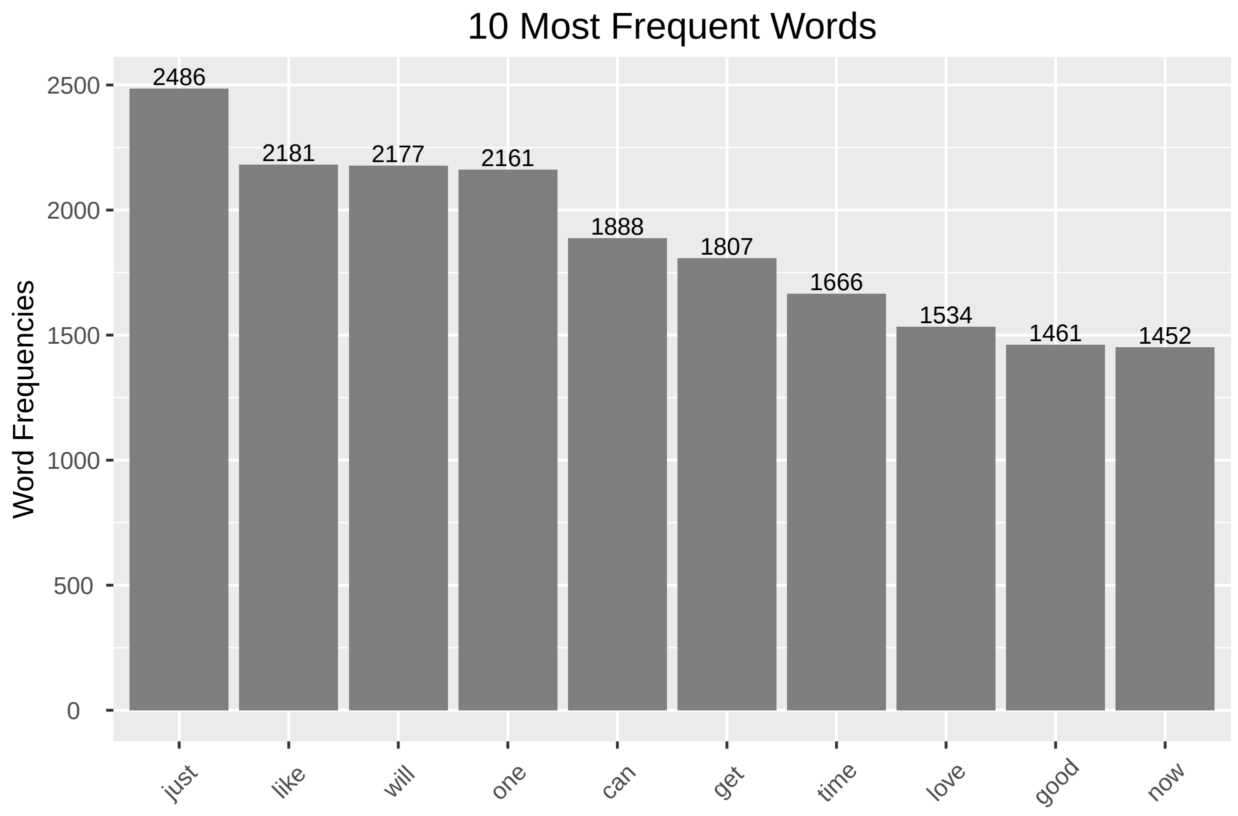
Exploratory Data Analysis

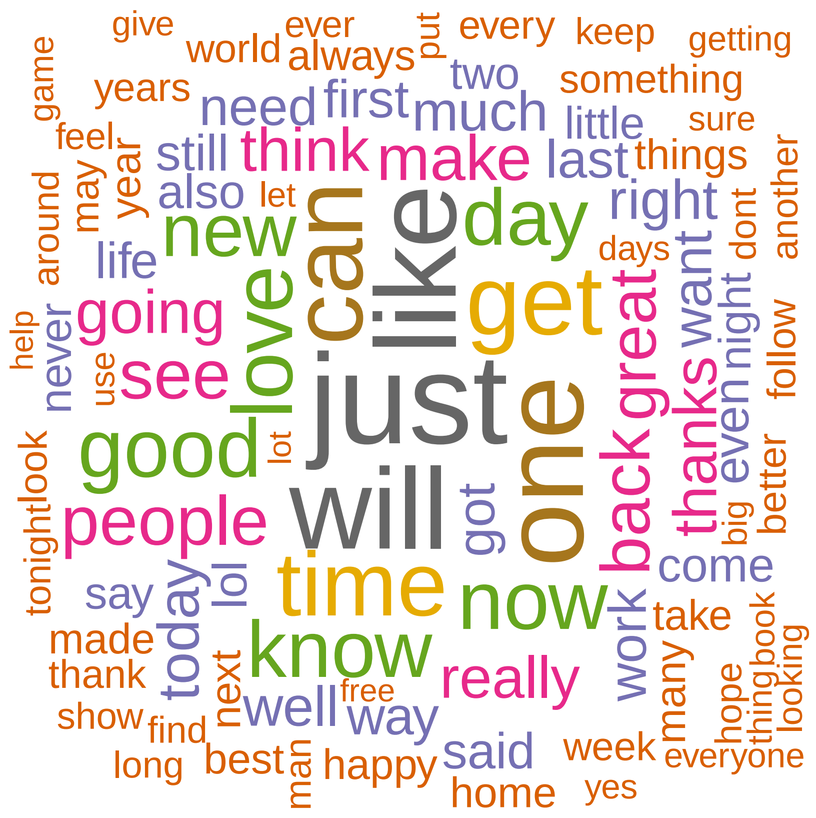
Exploratory data analysis will be performed to fulfill the primary goal for this report. Several techniques will be employed to develop an understanding of the training data which include looking at the most frequently used words, tokenizing and n-gram generation.

Word Frequencies

A bar chart and word cloud will be constructed to illustrate unique word frequencies.

```
## Warning: package 'wordcloud' was built under R version 4.2.3
```



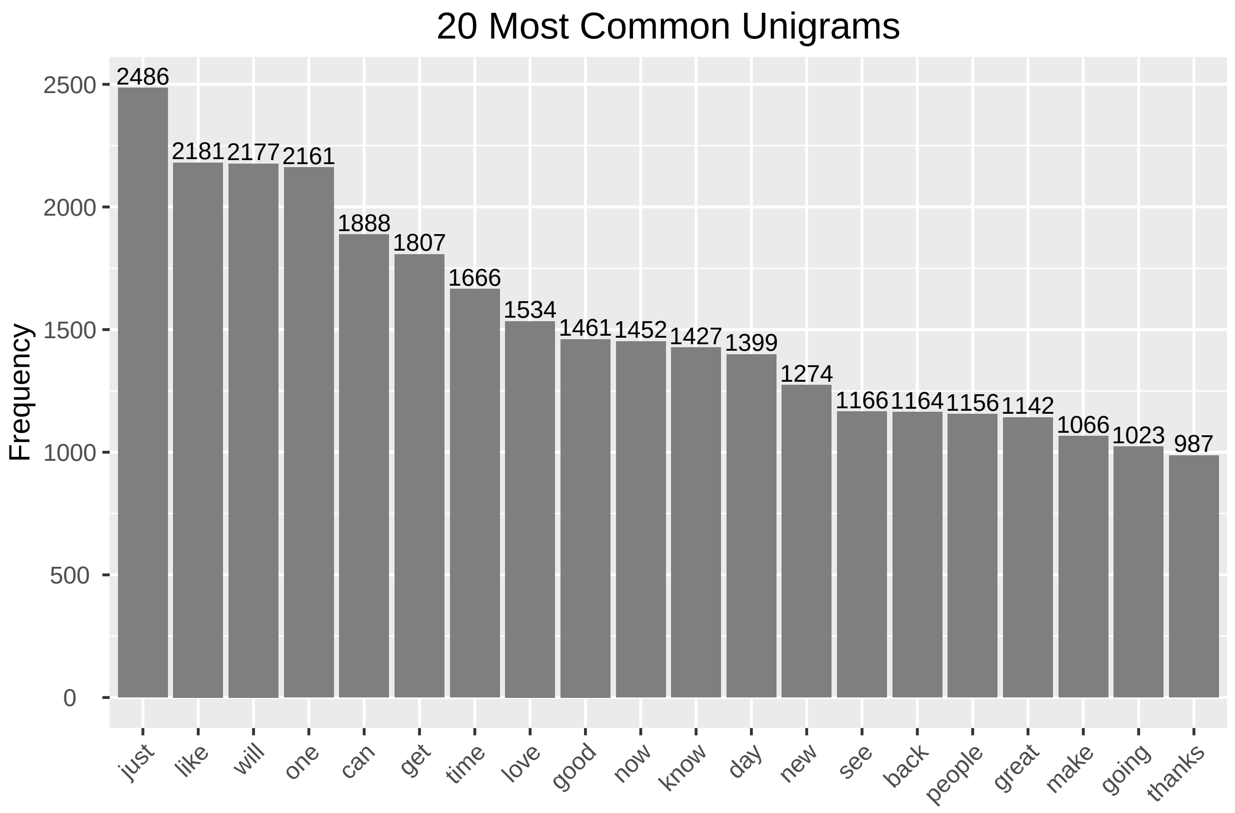


The source code for the word frequency bar chart and constructing the work cloud is attached as A.5 Word Frequencies in the Appendix section.

Tokenizing and N-Gram Generation

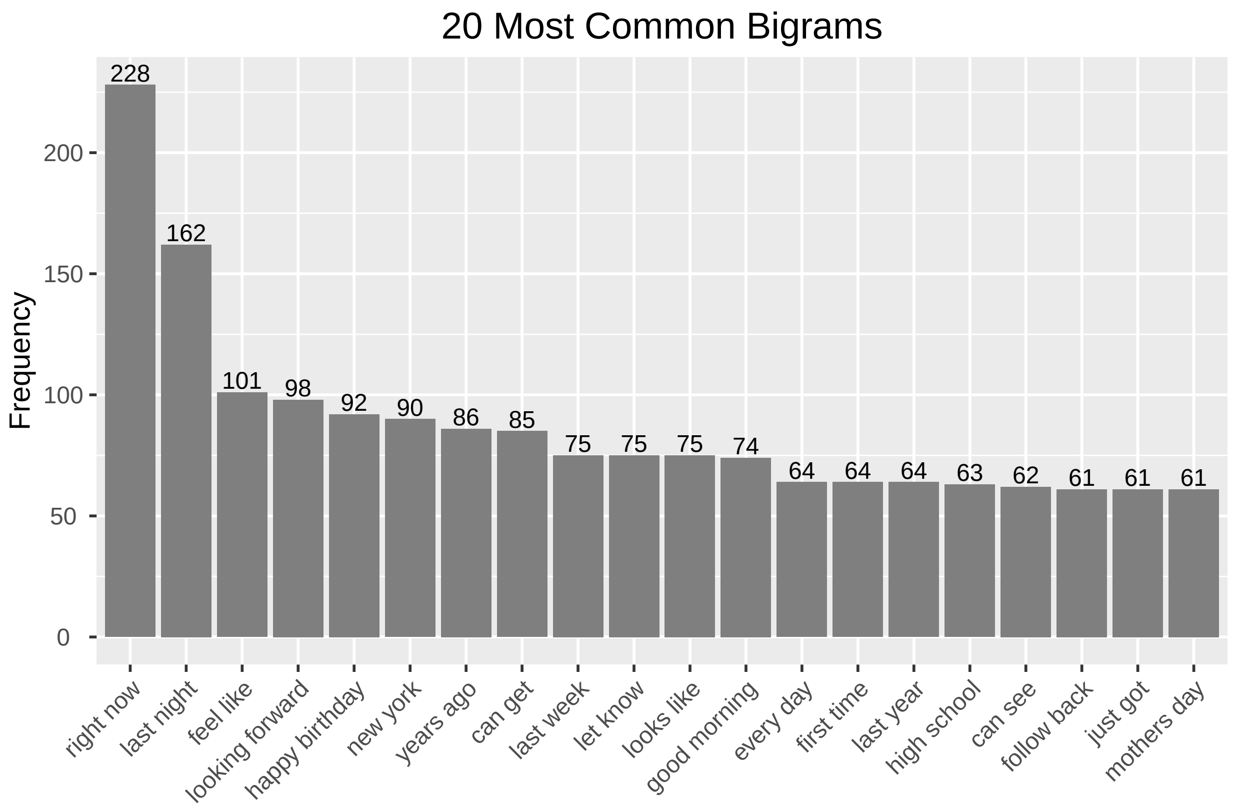
The predictive model I plan to develop for the Shiny application will handle uniqrams, bigrams, and trigrams. In this section, I will use the `RWeka` package to construct functions that tokenize the sample data and construct matrices of uniqrams, bigrams, and trigrams.

```
## Warning: package 'RWeka' was built under R version 4.2.3
```

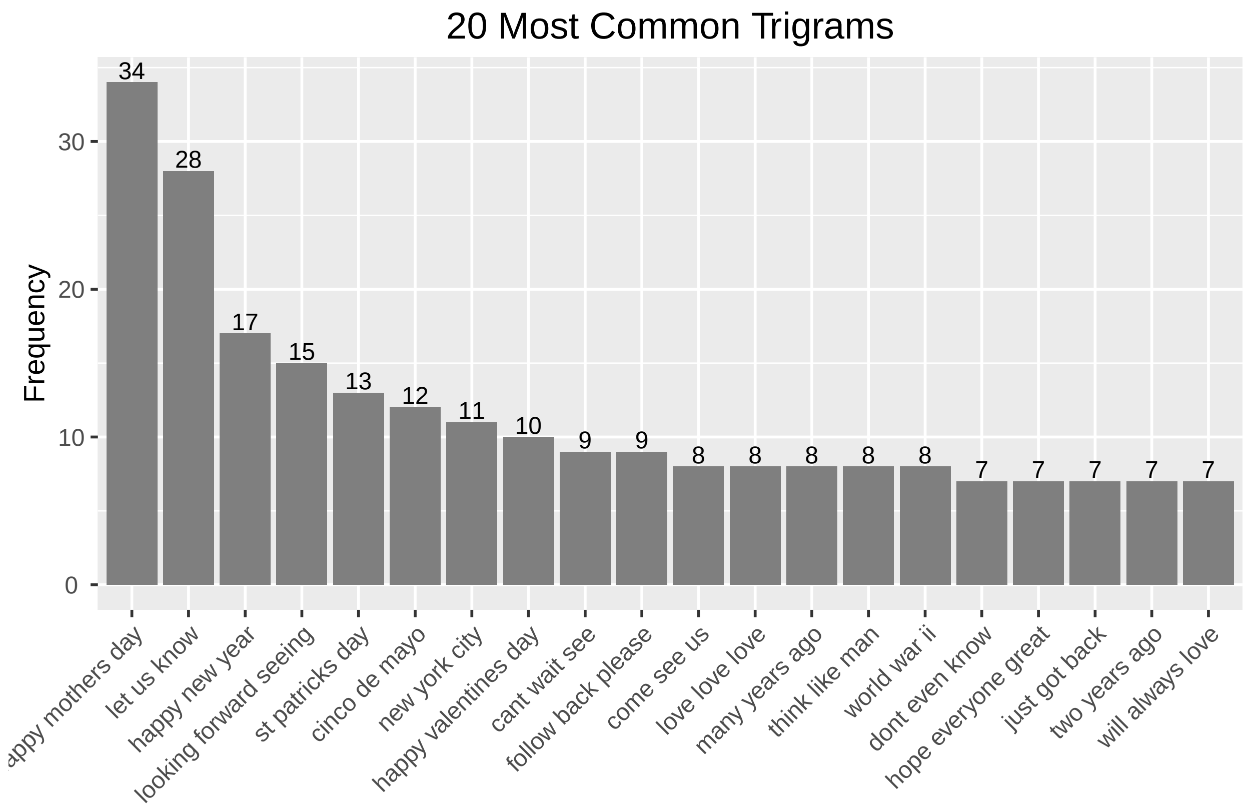


20 Most Common Unigrams
Frequency
0
500
1000
1500
2000
2500
2486
2181
2177
2161
1888
1807
1666
1534
1461
1452
1427
1399
1274
1166
1164
1156
1142
1066
1023
987
just
like
will
one
can
get
time
love
good
now
know
day
new
see
back
people
great
make
going
thanks

Unigrams


20 Most Common Bigrams
Frequency
0
50
100
150
200
228
162
101
98
92
90
86
85
75
75
75
74
64
64
64
63
62
61
61
61
right now
last night
feel like
looking forward
happy birthday
new york
years ago
can get
last week
let know
looks like
good morning
every day
first time
last year
high school
can see
follow back
just got
mothers day

Bigrams



Trigrams

The source code for this section is attached as A.6 Tokenizing and N-Gram Generation in the Appendix section.

Basic Project Plan

The final deliverable in the capstone project is to build a predictive algorithm that will be deployed as a Shiny app for the user interface. The Shiny app should take as input a phrase (multiple words) in a text box input and output a prediction of the next word.

The predictive algorithm will be developed using an n-gram model with a word frequency lookup similar to that performed in the exploratory data analysis section of this report. A strategy will be built based on the knowledge gathered during the exploratory analysis. For example, as n increased for each n-gram, the frequency decreased for each of its terms. So one possible strategy may be to construct the model to first look for the unigram that would follow from the entered text. Once a full term is entered followed by a space, find the most common bigram model and so on.

Another possible strategy may be to predict the next word using the trigram model. If no matching trigram can be found, then the algorithm would check the bigram model. If still not found, use the unigram model.

The final strategy will be based on the one that increases efficiency and provides the best accuracy.

Appendix

A.1 Basic Data Summary

Basic summary of the three text corpora.

```r
library(stringi)
library(kableExtra)

# assign sample size
sampleSize = 0.01

# file size
fileSizeMB <- round(file.info(c(blogsFileName,
                                newsFileName,
                                twitterFileName))$size / 1024 ^ 2)

# num lines per file
numLines <- sapply(list(blogs, news, twitter), length)

# num characters per file
numChars <- sapply(list(nchar(blogs), nchar(news), nchar(twitter)), sum)

# num words per file
numWords <- sapply(list(blogs, news, twitter), stri_stats_latex)[4,]

# words per line
wpl <- lapply(list(blogs, news, twitter), function(x) stri_count_words(x))

# words per line summary
wplSummary = sapply(list(blogs, news, twitter),
             function(x) summary(stri_count_words(x))[c('Min.', 'Mean', 'Max.')])
rownames(wplSummary) = c('WPL.Min', 'WPL.Mean', 'WPL.Max')

summary <- data.frame(
    File = c("en_US.blogs.txt", "en_US.news.txt", "en_US.twitter.txt"),
    FileSize = paste(fileSizeMB, " MB"),
    Lines = numLines,
    Characters = numChars,
    Words = numWords,
    t(rbind(round(wplSummary)))
)

kable(summary,
      row.names = FALSE,
      align = c("l", rep("r", 7)),
      caption = "") %>% kable_styling(position = "left")
```

A.2 Histogram of Words per Line

Histogram of words per line for the three text corpora.

```r
library(ggplot2)
library(gridExtra)

plot1 <- qplot(wpl[[1]],
               geom = "histogram",
               main = "US Blogs",
               xlab = "Words per Line",
               ylab = "Frequency",
               binwidth = 5)

plot2 <- qplot(wpl[[2]],
               geom = "histogram",
               main = "US News",
               xlab = "Words per Line",
               ylab = "Frequency",
               binwidth = 5)

plot3 <- qplot(wpl[[3]],
               geom = "histogram",
               main = "US Twitter",
               xlab = "Words per Line",
               ylab = "Frequency",
               binwidth = 1)

plotList = list(plot1, plot2, plot3)
do.call(grid.arrange, c(plotList, list(ncol = 1)))

# free up some memory
rm(plot1, plot2, plot3)
```

A.3 Sample and Clean the Data

```
# set seed for reproducibility
set.seed(450067)

# sample all three data sets
sampleBlogs <- sample(blogs, length(blogs) * sampleSize, replace = FALSE)
sampleNews <- sample(news, length(news) * sampleSize, replace = FALSE)
sampleTwitter <- sample(twitter, length(twitter) * sampleSize, replace = FALSE)

# remove all non-English characters from the sampled data
sampleBlogs <- iconv(sampleBlogs, "latin1", "ASCII", sub = "")
sampleNews <- iconv(sampleNews, "latin1", "ASCII", sub = "")
sampleTwitter <- iconv(sampleTwitter, "latin1", "ASCII", sub = "")

# combine all three data sets into a single data set and write to disk
sampleData <- c(sampleBlogs, sampleNews, sampleTwitter)
sampleDataFileName <- "C:/Users/Kwasi1/Desktop/Rcoursera/Coursera-SwiftKey/final/en_US/en_US.sample.txt
con <- file(sampleDataFileName, open = "w")
writeLines(sampleData, con)
close(con)

# get number of lines and words from the sample data set
sampleDataLines <- length(sampleData);
sampleDataWords <- sum(stri_count_words(sampleData))

# remove variables no longer needed to free up memory
rm(blogs, news, twitter, sampleBlogs, sampleNews, sampleTwitter)
```

A.4 Build Corpus

```
library(tm)

# download bad words file
download.file("http://www.cs.cmu.edu/~biglou/resources/bad-words.txt","bad-words.txt")
badWordsFile <- "C:/Users/Kwasi1/Desktop/Rcoursera/bad-words.txt"

buildCorpus <- function (dataSet) {
    docs <- VCorpus(VectorSource(dataSet))
    toSpace <- content_transformer(function(x, pattern) gsub(pattern, " ", x))

    # remove URL, Twitter handles and email patterns
    docs <- tm_map(docs, toSpace, "(f|ht)tp(s?)://(.*)[.][a-z]+")
    docs <- tm_map(docs, toSpace, "@[^\\s]+")
    docs <- tm_map(docs, toSpace, "\\b[A-Z a-z 0-9._ - ]*[@](.*?)[.]{1,3} \\b")

    # remove profane words from the sample data set
    con <- file(badWordsFile, open = "r")
    profanity <- readLines(con, encoding = "UTF-8", skipNul = TRUE)
    close(con)
    profanity <- iconv(profanity, "latin1", "ASCII", sub = "")
    docs <- tm_map(docs, removeWords, profanity)

    docs <- tm_map(docs, tolower)
    docs <- tm_map(docs, removeWords, stopwords("english"))
    docs <- tm_map(docs, removePunctuation)
    docs <- tm_map(docs, removeNumbers)
    docs <- tm_map(docs, stripWhitespace)
    docs <- tm_map(docs, PlainTextDocument)
    return(docs)
}

# build the corpus and write to disk (RDS)
corpus <- buildCorpus(sampleData)
saveRDS(corpus, file = "C:/Users/Kwasi1/Desktop/Rcoursera/Coursera-SwiftKey/final/en_US/en_US.corpus.rds

# convert corpus to a dataframe and write lines/words to disk (text)
corpusText <- data.frame(text = unlist(sapply(corpus, '[', "content")), stringsAsFactors = FALSE)
con <- file("C:/Users/Kwasi1/Desktop/Rcoursera/Coursera-SwiftKey/final/en_US/en_US.corpus.txt", open =
writeLines(corpusText$text, con)
close(con)

kable(head(corpusText$text, 10),
      row.names = FALSE,
      col.names = NULL,
      align = c("l"),
      caption = "First 10 Documents") %>% kable_styling(position = "left")

# remove variables no longer needed to free up memory
rm(sampleData)
```

A.5 Word Frequencies

```r
library(wordcloud)
library(RColorBrewer)

tdm <- TermDocumentMatrix(corpus)
freq <- sort(rowSums(as.matrix(tdm)), decreasing = TRUE)
wordFreq <- data.frame(word = names(freq), freq = freq)

# plot the top 10 most frequent words
g <- ggplot (wordFreq[1:10,], aes(x = reorder(wordFreq[1:10,]$word, -wordFreq[1:10,]$fre),
                                  y = wordFreq[1:10,]$fre ))
g <- g + geom_bar( stat = "Identity" , fill = I("grey50"))
g <- g + geom_text(aes(label = wordFreq[1:10,]$fre), vjust = -0.20, size = 3)
g <- g + xlab("")
g <- g + ylab("Word Frequencies")
g <- g + theme(plot.title = element_text(size = 14, hjust = 0.5, vjust = 0.5),
               axis.text.x = element_text(hjust = 0.5, vjust = 0.5, angle = 45),
               axis.text.y = element_text(hjust = 0.5, vjust = 0.5))
g <- g + ggtitle("10 Most Frequent Words")
print(g)

# construct word cloud
suppressWarnings (
    wordcloud(words = wordFreq$word,
              freq = wordFreq$freq,
              min.freq = 1,
              max.words = 100,
              random.order = FALSE,
              rot.per = 0.35,
              colors=brewer.pal(8, "Dark2"))
)

# remove variables no longer needed to free up memory
rm(tdm, freq, wordFreq, g)
```

A.6 Tokenizing and N-Gram Generation

Tokenize Functions

```r
library(RWeka)

unigramTokenizer <- function(x) NGramTokenizer(x, Weka_control(min = 1, max = 1))
bigramTokenizer <- function(x) NGramTokenizer(x, Weka_control(min = 2, max = 2))
trigramTokenizer <- function(x) NGramTokenizer(x, Weka_control(min = 3, max = 3))
```

Unigrams

```r
# create term document matrix for the corpus
unigramMatrix <- TermDocumentMatrix(corpus, control = list(tokenize = unigramTokenizer))
```

```
# eliminate sparse terms for each n-gram and get frequencies of most common n-grams
unigramMatrixFreq <- sort(rowSums(as.matrix(removeSparseTerms(unigramMatrix, 0.99))), decreasing = TRUE
unigramMatrixFreq <- data.frame(word = names(unigramMatrixFreq), freq = unigramMatrixFreq)

# generate plot
g <- ggplot(unigramMatrixFreq[1:20,], aes(x = reorder(word, -freq), y = freq))
g <- g + geom_bar(stat = "identity", fill = I("grey50"))
g <- g + geom_text(aes(label = freq ), vjust = -0.20, size = 3)
g <- g + xlab("")
g <- g + ylab("Frequency")
g <- g + theme(plot.title = element_text(size = 14, hjust = 0.5, vjust = 0.5),
               axis.text.x = element_text(hjust = 1.0, angle = 45),
               axis.text.y = element_text(hjust = 0.5, vjust = 0.5))
g <- g + ggtitle("20 Most Common Unigrams")
print(g)
```

Bigrams

```
# create term document matrix for the corpus
bigramMatrix <- TermDocumentMatrix(corpus, control = list(tokenize = bigramTokenizer))

# eliminate sparse terms for each n-gram and get frequencies of most common n-grams
bigramMatrixFreq <- sort(rowSums(as.matrix(removeSparseTerms(bigramMatrix, 0.999))), decreasing = TRUE)
bigramMatrixFreq <- data.frame(word = names(bigramMatrixFreq), freq = bigramMatrixFreq)

# generate plot
g <- ggplot(bigramMatrixFreq[1:20,], aes(x = reorder(word, -freq), y = freq))
g <- g + geom_bar(stat = "identity", fill = I("grey50"))
g <- g + geom_text(aes(label = freq ), vjust = -0.20, size = 3)
g <- g + xlab("")
g <- g + ylab("Frequency")
g <- g + theme(plot.title = element_text(size = 14, hjust = 0.5, vjust = 0.5),
               axis.text.x = element_text(hjust = 1.0, angle = 45),
               axis.text.y = element_text(hjust = 0.5, vjust = 0.5))
g <- g + ggtitle("20 Most Common Bigrams")
print(g)
```

Trigrams

```
# create term document matrix for the corpus
trigramMatrix <- TermDocumentMatrix(corpus, control = list(tokenize = trigramTokenizer))

# eliminate sparse terms for each n-gram and get frequencies of most common n-grams
trigramMatrixFreq <- sort(rowSums(as.matrix(removeSparseTerms(trigramMatrix, 0.9999))), decreasing = TRU
trigramMatrixFreq <- data.frame(word = names(trigramMatrixFreq), freq = trigramMatrixFreq)

# generate plot
g <- ggplot(trigramMatrixFreq[1:20,], aes(x = reorder(word, -freq), y = freq))
g <- g + geom_bar(stat = "identity", fill = I("grey50"))
g <- g + geom_text(aes(label = freq ), vjust = -0.20, size = 3)
g <- g + xlab("")
g <- g + ylab("Frequency")
g <- g + theme(plot.title = element_text(size = 14, hjust = 0.5, vjust = 0.5),
                axis.text.x = element_text(hjust = 1.0, angle = 45),
                axis.text.y = element_text(hjust = 0.5, vjust = 0.5))
g <- g + ggtitle("20 Most Common Trigrams")
print(g)
```