Playing with Lyrics

Introduction

Everyone loves pop music, while this nova in entertainment industry has gone through numerous changes in the past 50 years, especially from handmade to mass produced. Lyrics, as an essential part of song, has thus drawn much attention. People are crazy to know everything about lyrics, from the most frequently used words to he luring charm. Then it comes the question, whether lyric changes over time and, if there are golden rules in writing lyrics.

People's preference of information density in words and their pronunciation fluctuate over periods. Whether obscure parallelism or catchy candyfloss are more favored? Do people associate feelings with certain sounds? To answer these questions, we start with sentiment analysis and rhyme detection.

From our research, **lyrics become various and neutral over time.** The growing vocabulary and song length suggest a wider choice of words; After a pursuit of complexity, lyrics return to a neutral level, neither too complicated nor too simple; Less positive emotion is conveyed in pop songs. On the other hand, rhyme does not change much in the past 5 decades, while **they do imply certain kinds of sentiment.**

Methods

1. Data description

As Tab.1 shows, our data set contains lyrics and other information from 52 years of Billboard Top-100 songs(1965-2016).

Year	1965
Rank	1
Song	Wooly Bully
Artist	Sam the Sham and the Pharaohs
Lyrics	Matty told Hatty About a thing she saw Had two big horn…
Source	2

Tab.1 Data Example

The data is generated in two steps:
First, we get each year's chart of Billboard Top-100 songs from Wikipedia and combine them together
(Eg. http://en.wikipedia.org/wiki/Billboard_Year-End_Hot_100_singles_of_1965).

Then, we scrape lyrics of each song from the following websites:

1. http://metrolyrics.com
2. http://songlyrics.com
3. http://www.lyricsmode.com

Luckily, most URLs of lyrics are in same format, so we can get the lyrics within loop. For the missing lyrics, we search the URLs by ourselves. After deleting the pure music, we finally have 5072 songs with 6 features.

2. Information from words

Lyrics convey certain kinds of information, from which we choose to study entropy, complexity and sentiment.

2.1 Entropy: Average Information

Entropy refers to disorder or uncertainty. It's the expected value of the information contained in each message.

$$\text{Entropy} = -\sum_{i=1}^{n} p_i \log_b(p_i)$$

where n is the number of outcomes, p_i is the probability of the ith outcome, b is the carefully chosen base. In this scenario, words are treated as outcomes and entropy measures the density information in lyrics.

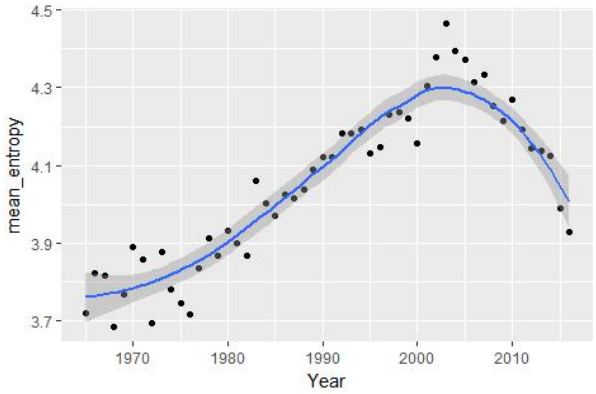


Fig.1 Average Word Entropy Each Year(1965-2016)

As Fig.1 shows, entropy increases with time before 2003 and then starts to decrease, as lyrics become complicated at first and then return to simple.

2.2 Complexity: Growing Vocabulary and Song Length

As Fig.2 shows, average word counts (both unique and total) have increased over time. Variance in word counts increased, perhaps due to greater genre diversity in the chart rankings over time.

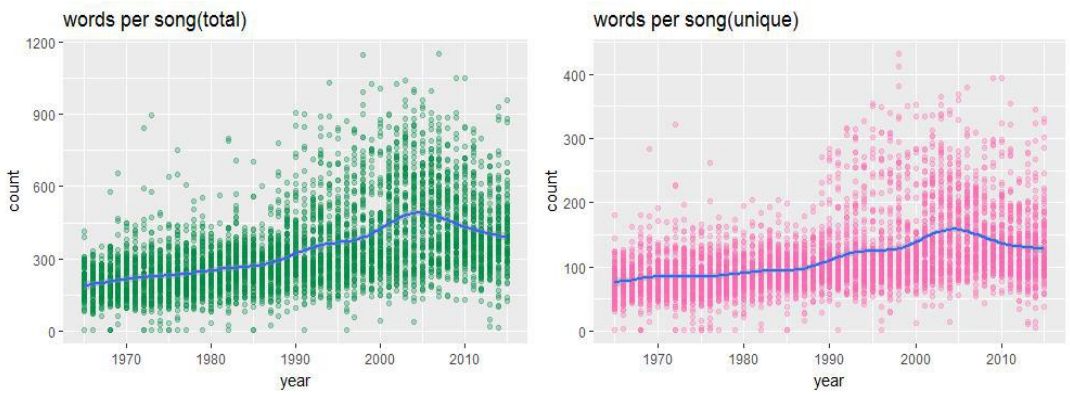


Fig.2 Words per Song(Total&Unique) vs. Year

2.3 Sentiment: Less Positive

There are three lexicons for sentiment analysis in R, nrc, bing and AFINN, all based on single words.

AFINN lexicon assigns a score to each word, with negative scores indicating negative sentiment and positive ones indicating the opposite. Fig.3 is the average sentiment score of each year.

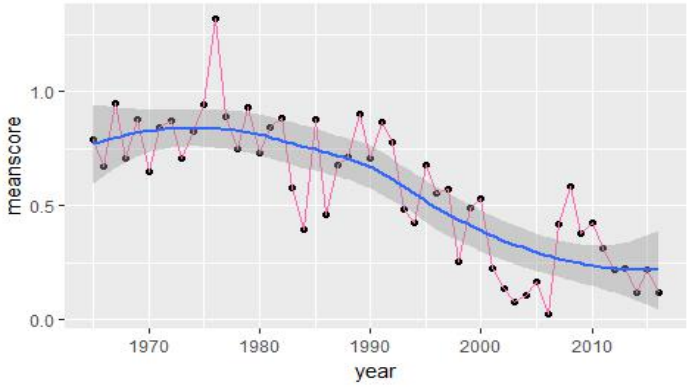


Fig.3 Sentiment Mean Score vs. Year

Nrc lexicon divides words into 10 categories. Fig.4 is the percentage of each sentiment.

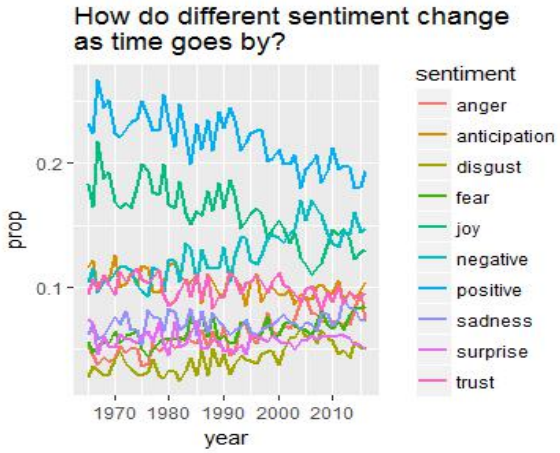


Fig.4 Different Sentiment vs. Year

Bing lexicon simply divides words into positive and negative categories.

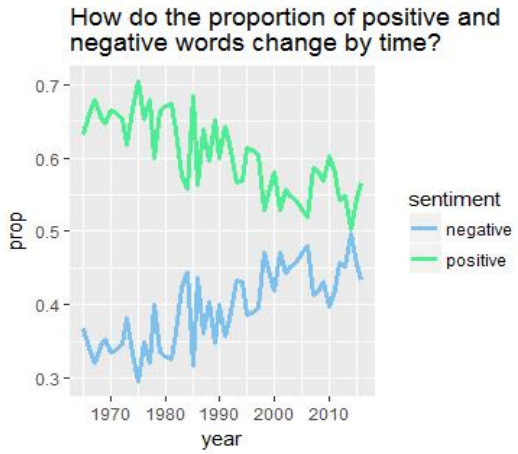


Fig.5 Proportion of Positive and Negative Sentiment per Year

3. Rhyme Analysis

Besides sentiment, rhyme is another obvious feature of song. A proper rhyme can create the right atmosphere and increase the emotional tension. Also, looping through the same phoneme makes it easier for listeners to follow the rhythm and thus leave them deeper impression. In this part, we give a method of getting the rhyme score and its distribution, with which we do some simple analysis.

3.1 Lyrics to Phonemes

Assumption 3.1: The last three phonemes in a word determine its rhyme.

Assumption 3.2: Each phoneme can be given a type, either "C" for consonant or "V" for vowel.

Then for each word, a data frame can be constructed(as Tab.3 shows), with the phonetic symbols and their types being variables.

3.1.1 Casting Words into Phonetic Symbols

The CMU Pronouncing Dictionary(http://www.speech.cs.cmu.edu/cgi-bin/cmudict), which is a data frame as Tab.2 shows, is used to cast words into phonetic symbols.

word	Phnm1	Phnm2	Phnm3	Phnm4	Phnm5	Phnm6	Phnm7	Phnm8	.....	Phnm35
RESTAURANT	R	EH1	S	T	ER0	AA2	N	T	.....	
RESTAURANT(1)	R	EH1	S	T	R	AA2	N	T	.....	

Tab.2 CMUDict-0.7b

As Tab.2 shows, there exist words that have 2 or more pronunciations, for which we simply list all the pronunciations. Also, the given phonetic symbols include stress, which is indicated by numbers. Since stress in songs is usually determined by beats instead of the pronunciation of words, it does not make much difference that we exclude those

numbers.

3.1.2 Types of Phonetic Symbols

The type of a phonetic symbol is defined as follow:

1. If a phonetic symbol is in

"AA","AE","AH","AO","AW","AY","EH","ER","EY","IH","IY","OW","OY","UH","UW"

It is certainly a monosyllable vowel and thus should be given the type "V";

2. If a phonetic symbol is in

"B","CH","D","DH","F","G","HH","JH","K","P","S","SH","T","TH","V","W","Y","Z","ZH"

It is certainly a consonant and thus should be given the type "C";

3. If a phonetic symbol is in "NG","N","R","L":

1) If the phonetic symbol is in "N","R","L" and is followed by a vowel, this phonetic symbol is a consonant;

2) If the phonetic symbol is in "N","R","L" and is followed by a consonant, this phonetic symbol belongs to a vowel phoneme;

3) Vowel "N" and "NG" is combined together as "-N".

For example, the types of phonetic symbols in the word "restaurant" are shown in Tab.3.

word	Phnm1	Phnm2	Phnm3	Phnm4	Phnm5	Phnm6	Phnm7	Phnm8
RESTAURANT	R(C)	EH(V)	S(C)	T(C)	ER(V)	AA(V)	-N(V)	T(C)
RESTAURANT	R(C)	EH(V)	S(C)	T(C)	R(C)	AA(V)	-N(V)	T(C)

Tab.3 Dealing with the Types of Phonetic Symbols

3.1.3 Deriving Phonemes from Phonetic Symbols

A Phoneme includes either of the 3 phonetic symbol groups below:

1. As much continuous consonant as possible, with each one being a phoneme at the same location;

2. As much continuous "-N", vowel "R" or vowel "L" as possible, and a monosyllable vowel in front of them;

3. A monosyllable vowel, with no "-N", vowel "R" or vowel "L" following it.

For example, the last 3 phonemes in the word "restaurant" is shown in Tab.4.

Phoneme	T(C)	AA -N	ER	T	AA -N	R	T	S
Type	C	V	V	C	V	C	C	C
Location	1	2	3	1	2	3	3	3

Tab.4 Deriving Phonemes from Phonetic Symbols

3.2 Phonemes to Rhymes

3.2.1 Types of Rhymes

Word	Phoneme3	Phoneme2	Phoneme1
Magicians	ci	an	s
	SH(3)	AH -N(1)	S(2)
Professions	ssi	on	s
	SH(3)	AN -N(1)	S(2)
Profession	e	ssi	on
	EH	SH(3)	AN -N(1)

Tab.5 Types of Rhymes

If two words are considered rhyme, their phonemes should satisfy either of the 3 conditions below:

1. Rhyming Last Vowel: Vowel phonemes with location in {1,2} share the same monosyllable vowel and at least one "-N", vowel "R" or vowel "L"(if there are any).
2. Rhyming Last Consonant: Same consonant phonemes with location=1.
3. Rhyming Second Consonant: Same Consonant phonemes with location in {2,3}.
4.

Rhyming last vowel is the strongest type of rhyming because it is the easiest to feel and gives a strong sense of repetition; rhyming last consonant is not as strong, but it helps to make the rhythm more obvious; rhyming second consonant is the weakest, it is difficult to feel and only has potential influence.

3.2.2 Frequency of Candidate Rhyme Appearance.

Assumption 3.3: The last word of each sentence determines the rhyme of a song.

Suppose m: total number of sentences in the lyrics

Ph_k: kth candidate rhyming phoneme

t_k: kth rhyming type

m_k: number of sentences with (ph_k, t_k)

For each k, add (ph_k, t_k) to the rhyme list and define its rhyme percentage as $p_k=m_k/m$ if either condition below is satisfied:

1) $m_k>4$;

2) $1<m_k\leq 4$, and there exists 2 sentences S_i and S_j, $|i-j|\leq 2$ such that (ph_k, t_k) appears in both of the sentences.

Repeat this procedure for all the three phonemes in the last word of each sentence, and we can get a data frame of the rhyme in a song as Tab.6 Shows.

Phoneme	Type	Percentage	Location
SH	C	p_1	{2,3}
AH -N	V	p_2	{1,2}
S	C	p_3	{1}

Tab.6 Frequency of Candidate Rhyme Appearance.

3.3 Score Computation

Let n_k=[times rhyme (ph_k,t_k) appears in a song]/[total number of words in a song]

And for Location≠{1}, suppose ph_k appears n_{k1} times at location l_{k1} and appears n_{k2} times at location l_{k2}(l_{k1}>l_{k2}), let

AvgLocation $l_k=(n_{k1}l_{k1}+n_{k2}l_{k2})/(n_{k1}+n_{k2})$

Weight $w_k=(n_{k1}L_k+n_{k2}U_k)/(n_{k1}+n_{k2})$

where l_{k1}, l_{k2}, L_k, U_k are listed in Tab.7.

Phoneme	Type	AvgLocation	Appearance	Percentage	Weight
SH	C	$2<l_1<3$	n_1	p_1	$1<w_1<2$
AH -N	V	$1<l_2<2$	n_2	p_2	$4<w_2<5$
S	C	$l_3=1$	n_3	p_3	$w_3=3$

Tab.7 Score Computation

Define Rhyme=I{$\sum_k p_k \geq 2$}, which is an indicator of whether a song is rhyming or not.

Define Score=$\sum_k n_k w_k$, which is an indicator of how strong the rhyme is in a song. We can also get the distribution of each phoneme score within a song, namely $s_k=n_k w_k/\sum_k n_k w_k$.

3.4 Accuracy Test

We randomly chose 100 songs from the data set and let our friends determine whether they rhyme or not, and compared the results with those in our model. Then we got a 2x2 table as Tab.8 shows.

		Model	
		Not	Rhyme
Actual	Not	1	6
	Rhyme	22	71

Tab.8 Accuracy Test

And we tried to assess the result using the following criteria:

(1) Accurate Rate AR=(TN+TP)/(TN+TP+FN+FP);

(2) Detection Rate DR=TP/(TN+TP+FN+FP);

(3) Sensitivity SE=TP/(TP+FN);

(4) Specificity SP=TN/(TN+FP);

As Tab.9 shows, the method is much better than random choice.

AR	DR	SE	SP
0.72	0.71	0.92	0.04

Tab.9 Assessment Table

3.5 Univariate Plots

After getting the rhyme score for each song, some simple analysis can be done to

explore the relationship between rhyme and time as well as average word length.

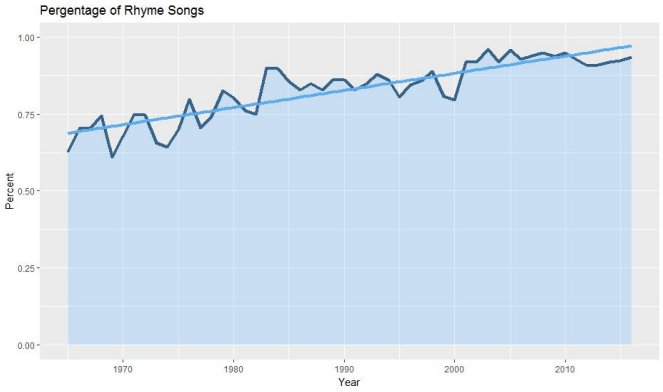


Fig.6 Year vs. Rhyme Percentage

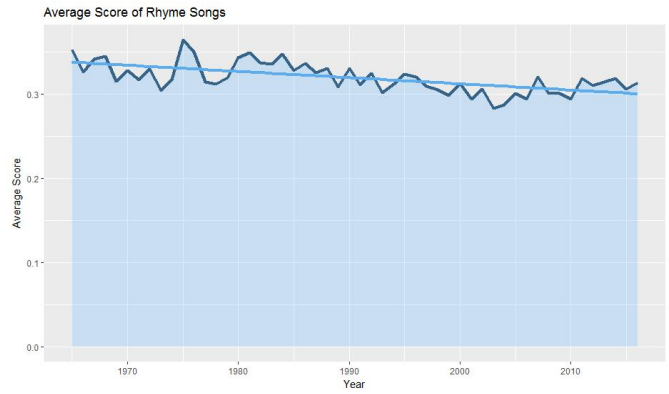
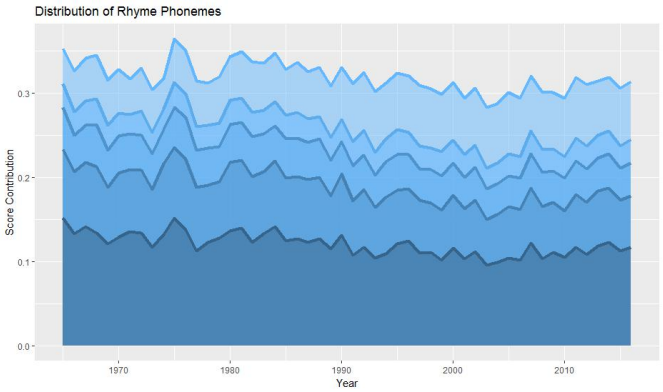


Fig.7 Year vs. Average Rhyme Score

As Fig.6 and Fig.7 show, the number of rhyme songs in the chart increases with time, while the average score of rhyme songs decreases. Also, if we take the increasing word entropy into consideration, we can see a trade between tight rhyme and rich content.

As Fig.8 shows, the distribution of scores is quite stationary. The first plot list the average proportions of the largest 5 rhyme scores of each song, and the second plot is the proportions of vowel rhyme scores and consonant rhyme scores. Artists tend to keep their habit of changing rhymes, and clearly vowel rhymes counts more than consonant ones.



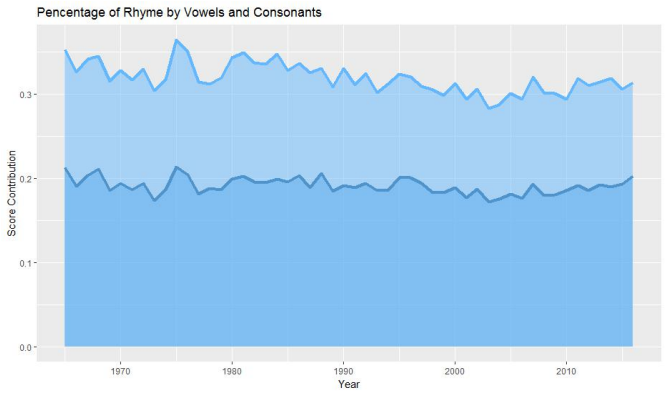


Fig.8 Year vs.Distribution of Rhyme Score

3.6 Multivariate Comparison

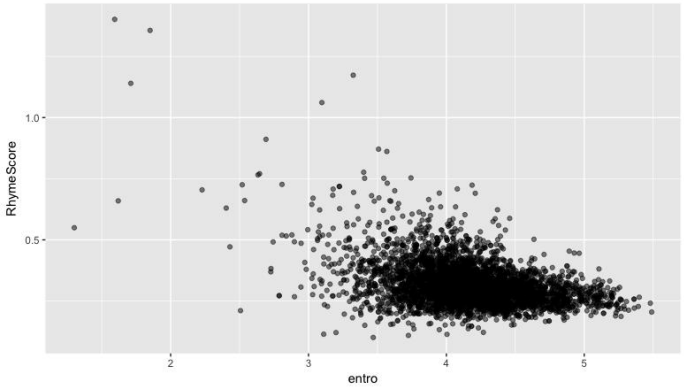


Fig.9 Rhyme Score vs. Entropy

As Fig.9 shows, rhyme-score is negative correlated with entropy, and the variance of rhyming score goes down as entropy goes up. This is consistent with the preview context.

4. Sentiment and Rhyme

It is not a new argument that rhymes in poetry helps to express certain kinds of mood. (Search "Rhyme Sentiment" on Google Scholar for details). By relating lyrics to its older form, poems, we want to know the relationship between sentiment and rhyme, in other words, what rhymes give rise to which kind of sentiment.

Our data has been transformed into the following example:

song	AA	...	ZH	anger	...	trust
Woolly Bully	0	...	0	1	...	0

Tab 4.1 Sample Point

The first column is the song name, the other columns are 67 different phonemes (1 = used for rhyme, 0 = otherwise) and 8 kinds of sentiments in the song (1 = exist, 0 = not exist).

4.1 Lasso-Logistic Model

We here use lasso-logistic model, where the response variable is a certain kind of sentiment, and the covariates are the phonemes. Since the response is binary, and the phonemes are not all necessary for expressing the sentiment, we use this model to select important covariates.

4.2 Interpretation of Results

The procedure deals with 8 kinds of sentiments and the results are lengthy, sentiment "joy" is used as an example. Before modeling, we randomly spare 10% data as a test set, cross validation is then used on the training set to select the best lambda. Fig 4.1 shows the shrinkage of coefficients with different lambda and Fig 4.2 shows the deviance of the model with different lambda. Thus, the best lambda is 0.0063.

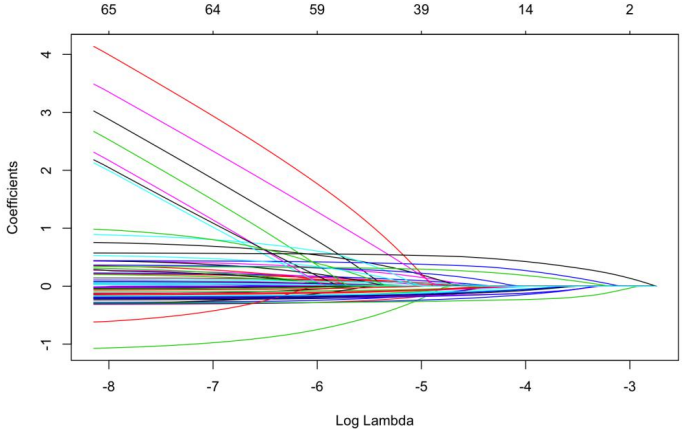


Fig 4.1: the shrinkage of coefficients

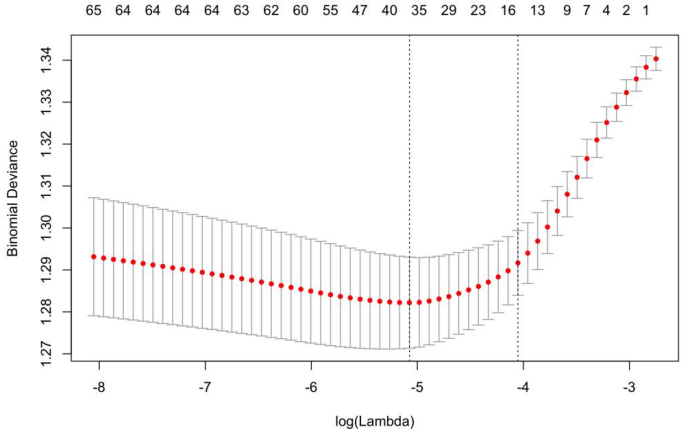


Fig 4.2: the deviance of the model with different lambda

The final model is

$$log\left(\frac{P(joy=1|phoneme)}{1-P(joy=1|phoneme)}\right) \sim (AA) + \left(AA-N\right) + (AA\,R) + (AE) + (AH) + (AO-N)$$
$$+ (AO\,R) + (AW) + (AW-N) + (AY-N) + (B) + (CH) + (D) + (DH)$$
$$+ (EH) + (EH-N) + (ER) + (ER\,R) + (EY) + (HH) + (IH) + (IH\,L) + (IY)$$
$$+ (IY-N) + (JH) + (K) + (M) + (OW) + (P) + (R) + (T) + (UH) + (UW)$$
$$+ (UW-N) + (V) + (W) + (Y) + (Z) + (ZH)$$

Tab 4.2 lists the top 5 absolute values.

phoneme	coefficient
V	0.5325247
IY	0.3823923
IH L	0.3558334
Y	0.2967629
AA L	-0.2727120

Tab 4.2: top 5 coefficients

For example, the log odds ratio will increase by 0.5325 when "V" is used as a rhyme. That means, artists tend to rhyme on "V" when they convey a sense of joy. To illustrate, "love", which rhymes on "V" and belongs to the joy category in nrc lexicon, is often used in this scenario.

Model Evaluation

To evaluate the performance and sensitivity of the model, we give the accuracy based on both training set and test set, respectively 64.17% and 65.23%. This is stable but not very satisfactory. Also, Fig 3.3 shows the ROC (Receiver Operating Characteristics) curve, the more concave the curve, the better the performance of model(If the False Positive Rate=True Positive Rate, the line represents randomly classification). The curve is higher than the diagonal line.

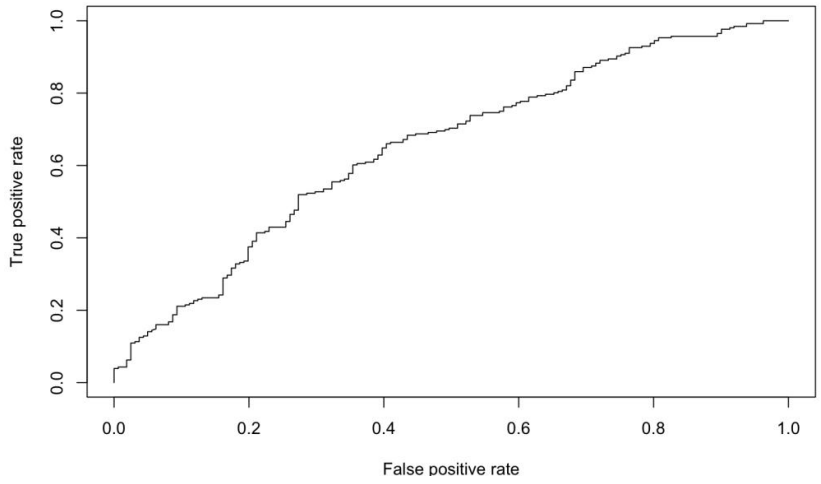


Fig 3.3: ROC curve

Conclusion and Limitation

As time goes by, the information contained in songs, such as entropy, song length and vocabulary, goes up in the first four decades, then it starts to decrease. On the other hand, sentiment expressed in lyrics is less and less positive (from Fig.1-5). This indicates that lyrics go into a more neutral state, which also suggests a growing diversity.

With respect to relationship between sentiment and rhyme, our Lasso-logistic model selects the most important rhymes for certain sentiments, some coefficients are shown in Tab. 4.2.

However, we still have some concerns. First, sentiment and rhyme is not naturally numeric, thus trying to quantify them brings limitation to objectivity. Additionally, when we analyze sentiment, we ignore the context. For example, when it comes to "don't love", the lexicon only matches "love", thus we wrongly assign positive score to it. What's more, the model's accuracy is not that high.

In the future,

1. Songs collected will not be restricted to the top 100, so that we can compare rhyming degree between Top-100 songs and other pop songs (Are rhyming songs easier to become popular than songs without rhyme?)
2. Include audio features and genres for future analysis.
3. Create an R package to deal with problems about rhyme and sentiment.

Appendix

An example of a rhyming song

Coldplay - Viva La Vida

I used to rule the world
Seas would rise when I gave the word
Now in the morning I sleep alone
Sweep the streets I used to own

I used to roll the dice
Feel the fear in my enemy's eyes
Listened as the crowd would sing
Now the old king is dead long live the king
One minute I held the key
Next the walls were closed on me
And I discovered that my castles stand
Upon pillars of salt and pillars of sand

I hear Jerusalem bells a-ringing
Roman cavalry choirs are singing
Be my mirror, my sword and shield
Missionaries in a foreign field
For some reason I can't explain
Once you'd gone there was never
Never an honest word
And that was when I ruled the world

It was a wicked and wild wind
Blew down the doors to let me in
Shattered windows and the sound of drums
People couldn't believe what I'd become
Revolutionaries wait
For my head on a silver plate
Just a puppet on a lonely string
Oh who would ever want to be king?

I hear Jerusalem bells a-ringing
Roman cavalry choirs are singing
Be my mirror, my sword and shield

My missionaries in a foreign field
For some reason I can't explain
I know St Peter won't call my name
Never an honest word
But that was when I ruled the world

Hear Jerusalem bells a-ringing
Roman cavalry choirs are singing
Be my mirror, my sword and shield
My missionaries in a foreign field
For some reason I can't explain
I know St Peter won't call my name
Never an honest word
But that was when I ruled the world

https://www.youtube.com/watch?v=dvgZkm1xWPE

An example of a not rhyming song

Taylor Swift-Love Story
we were both young when i first saw you
i close my eyes and the flashback starts
i'm standing there on a balcony in summer air
see the lights, see the party, the ball gowns
see you make your way through the crowd
and say hello, little did i know
that you were romeo, you were throwing pebbles
and my daddy said stay away from juliet
and i was crying on the staircase, begging you please don't go
and i said
romeo take me somewhere we can be alone
i'll be waiting, all there's left to do is run
you'll be the prince and i'll be this princess
it's a love story
baby, just say yes

so i sneak out to the garden to see you
we keep quiet 'cause we're dead if they knew
so close your eyes, escape this town for a little while
oh, oh, oh
'cause you were romeo, i was a scarlet letter

and my daddy said stay away from juliet
but you were everything to me, i was begging you please don't go
and i said
romeo take me somewhere we can be alone
i'll be waiting, all there's left to do is run
you'll be the prince and i'll be the princess
it's a love story
baby, just say yes
romeo save me try to tell me how it feels
this might be stupid boy, but its so real
don't be afraid now we'll get out of this mess
it's a love story
baby, just say yes

i got tired of waiting wondering if you were ever coming around
my faith in you is better
when i met you on the outskirts of town
and i said
romeo save me ive been feeling so alone
ill keep waiting for you but you never come
is this in my head, i don't know what to think
he fell to the ground and pulled out a ring
and said
marry me juliet you'll never have to be alone
i love you and that's all i really know
i talked to your dad you'll pick out a white dress
it's a love story
baby, just say yes

oh, oh, oh
we were both young when i first saw you

https://www.youtube.com/watch?v=8xg3vE8Ie_E