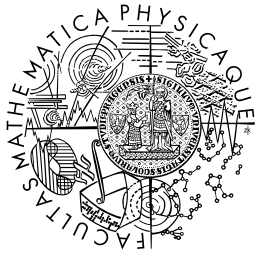

FACULTY
OF MATHEMATICS
AND PHYSICS
Charles University

MASTER THESIS

Patrícia Březinová

Computational analysis and synthesis of song lyrics

Institute of Formal and Applied Linguistics

Supervisor of the master thesis: Mgr. Martin Popel, Ph.D.
Study programme: Informatics
Study branch: Artificial Intelligence

Prague 2021

I declare that I carried out this master thesis independently, and only with the cited sources, literature and other professional sources. It has not been used to obtain another or the same degree.

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Dedication.

Title: Computational analysis and synthesis of song lyrics

Author: Patrícia Březinová

Institute: Institute of Formal and Applied Linguistics

Supervisor: Mgr. Martin Popel, Ph.D., Institute of Formal and Applied Linguistics

Abstract: Abstract.

Keywords: key words

Contents

Introduction

I can cite this Greene et al. [2010] when saying machine-generated poetry automatic evaluation is hard

1. Related work

mention here rhyme generating tools like rhymezone, redddy also mentions generation

1.1 Rhyme detection tools

Pridat nejaky nastroj co pouziva len CMU dictionary

1.1.1 SPARSAR

1.1.2 Unsupervised approach

EM algorithm

Reddy and Knight [2011] proposed a language-independent model for finding rhyme schemes in poetry. They created an unsupervised model based on EM algorithm that assigns the most probable rhyme scheme for each sequence of line-end words. It achieved good results when tested on annotated English and French corpus with poetry from 15^{th} to 20^{th} century. However its big pitfall lies in the fact that it is biased towards the rhyme schemes from golden data. It has a predefined set of all rhyme schemes found in tested data and those are the only ones it chooses from. For illustration, in 14-line stanza it can choose from 90 schemes which is only 0.00005% of all possible options. In 29% of cases from French corpus it has only one choice.

RhymeTagger

Plecháč [2018] came with a collocation-driven alternative named RhymeTagger. It uses the same dataset as previous approach with addition of a larger Czech poetry corpus. Each line-end word is transcribed into phonetic transcription and split into components (syllable peaks and consonant clusters). Probabilities for each component pair are calculated based on their vertical co-occurrence in line-end words. If two words have joined probability for all their components above the set threshold they are considered a rhyme. After all such pairs are classified, probabilities are iteratively recalculated. For words that were not successfully classified with this method, there is a fallback. The author observed that some words changed pronunciation over time and some didn't. Prior pronunciation can be therefore inferred from words with similar orthography. He calculated rhyme probability given character trigrams which helped achieve higher recall as seen in 1.1.

Deep-speare

As a part of their sonnet quatrain generating model, Lau et al. [2018] have a Rhyme component that identifies and generates rhymes. It is a unidirectional forward LSTM that learns to separate rhyming word pairs from non-rhyming.

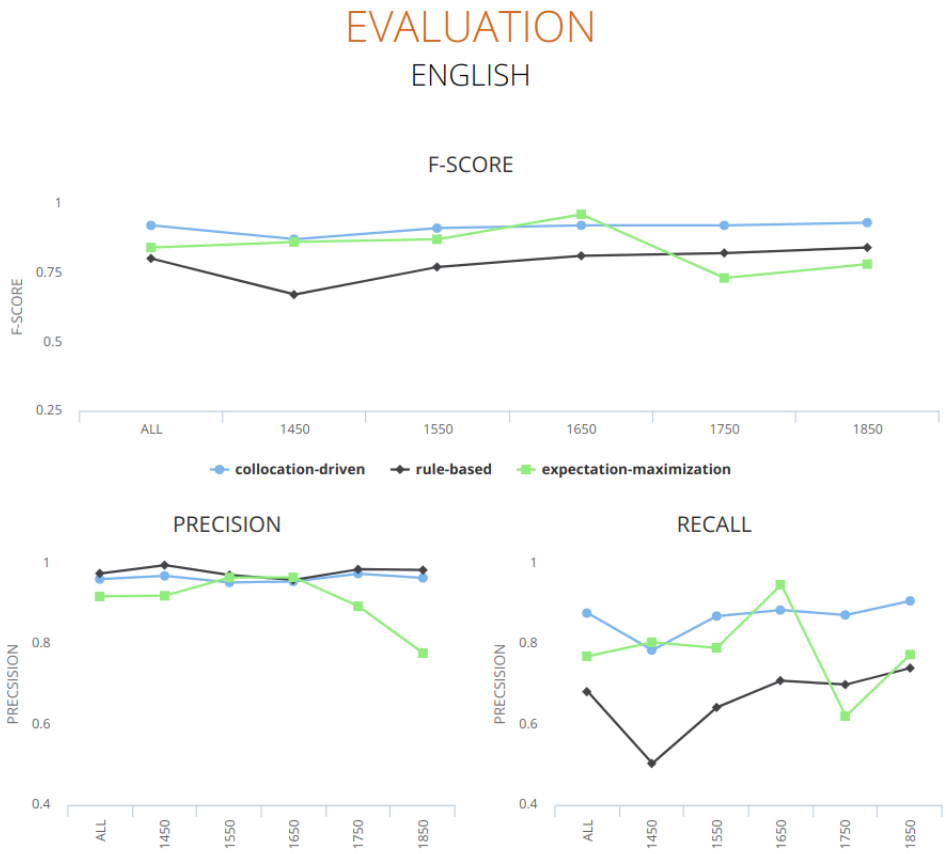

Figure 1.1: Evaluation of RhymeTagger on English corpus in comparison with EM algorithm and simple rule-based approach.[2]

They generate input by pairing one line-end word with the other three from the same quatrain what results in one rhyming pair and two non-rhyming. Additional non-rhyming pairs are generated with random word sampling. Then the model with margin-based loss learns the margin separating the best pair from all the others. It returns a cosine similarity score that estimates how well do two words rhyme.

To evaluate this model, authors used phoneme matching with CMU dictionary [3] and the EM model from Reddy and Knight [2011] trained on their own data and they were able to outperform both based on F1 score.

1.2 Visualization tools

In the following section we will describe existing visualization tools for poetry. There is no specific software for analyzing song lyrics in particular since they can be considered just a more structurally relaxed version of a regular poem.

[3] http://www.speech.cs.cmu.edu/cgi-bin/cmudict

1.2.1 Poem Viewer

The most complex and comprehensive visualization tool is Poem Viewer Abdul-Rahman et al. [2013]. With no need for complicated installations it is easily available for the writers as a web-based application as shown in Figure 1.2. Unfortunately, at the time of writing this thesis the upload of custom text was not working. Luckily, this is still an ongoing project so this might be just a temporary issue. Nevertheless there are some default poems available to demonstrate this software's capabilities.

Figure 1.2: Screenshot from Poem Viewer tool - visualizing Love by Elizabeth Barrett Browning.

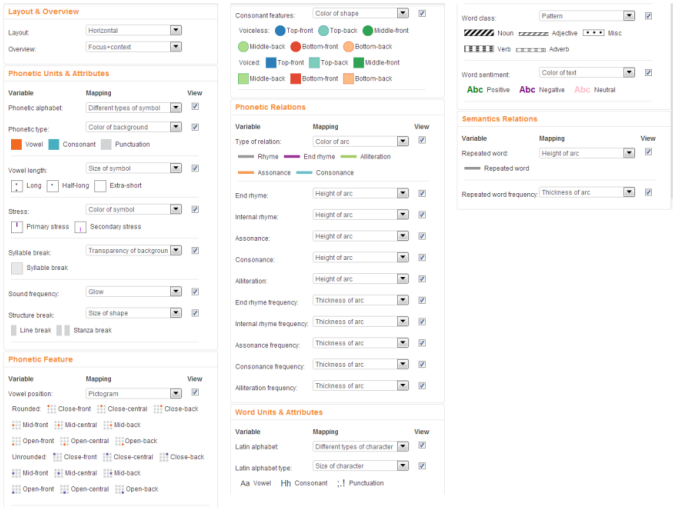

Figure 1.3: Available options and their default mappings in Poem Viewer.

Most of the analyzed features (shown in Figure 1.3 focuses on the phonetic aspects of the poem. After phonetic transcription to IPA users can analyze consonant features, vowel length and position, stress, syllables, word classes and

sentiment using color codes and markers. A second layout offers six different graphs/animations of tongue positions during each verse. Arcs are used to mark end rhyme, alliteration, assonance, consonance, their particular frequencies and repeating words.

Overall this software, although very elaborate, appears crowded and confusing for an inexperienced user. It is perhaps better suited for its original use case - a well structured poem - than less regular song lyrics.

1.2.2 SPARSAR

SPARSAR (Delmonte and Prati [2014]) is also a very interesting tool for poetry analysis and expressive Text-to-speech conversion. It is originally designed for a thorough examination of a very strictly structured Shakespeare's sonnets. To achieve this, it has to run analyses on many levels - and these results can be used to analyze any poem. It looks at the poem on three views: phonetic (pronunciation, consonant and vowel tongue position, assonances, etc.), poetic (metrical structure, rhyme schemes, acoustic length, etc.), and semantic (sentiment, methaphorically linked words, anaphora, etc.).

User can choose between a window application with graphs and diagrams or a headless mode with .xml output files. Its main disadvantage for our usecase is that it's written in Prolog and therefore is very strict on the input format and runs only under a specific older version of Ubuntu.

1.2.3 ProseVis

This Java desktop visualization tool by Clement et al. [2013] analyzes text through parts-of-speech, accent, phoneme, stress, tone, and break index. These features are extracted using OpenMary Text-to-speech system (Schröder et al. [2006]) and predictive classification. The authors believe their visualization will present the features to user in a more human readable form [4].

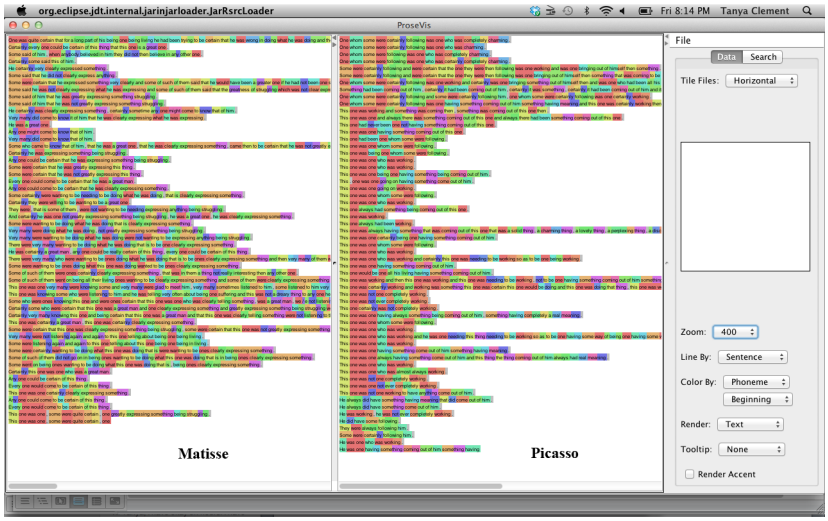

Figure 1.4: Comparison of two poems in ProseVis.[5]

[4]https://sourceforge.net/projects/prosevis/

1.2.4 Poemage and RhymeDesign

Poemage (McCurdy et al. [2015a]) and RhymeDesign (McCurdy et al. [2015b]) are both open-source applications with focus on analysis of sonic devices and sonic topology in poetry. Poemage focuses on complex structures of words connected through some sonic or linguistic resemblance across the space of the poem [6]. It is available for MacOS or Windows with a web version currently under development. In MacOS application RhymeDesign - which also provides the backend for Poemage - user can enter their poem and query for one of the default rhyme types or choose a custom rhyme type.

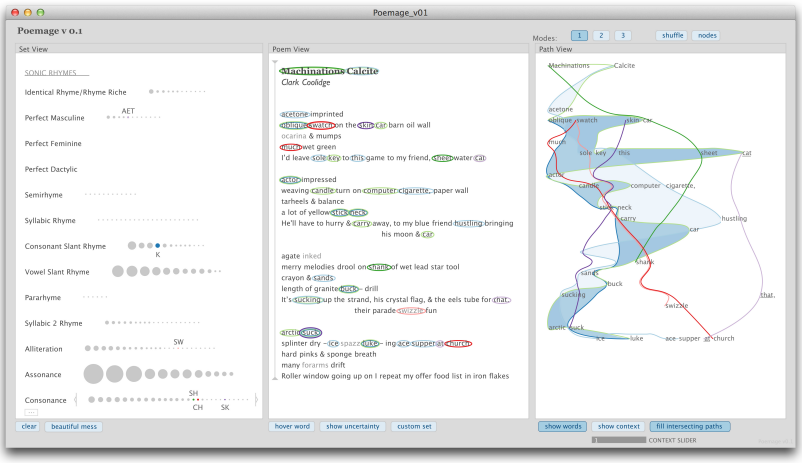

Figure 1.5: An example analysis in Poemage.

1.2.5 Ambiances

This software is unique in the fact that the analysis is integrated in the process of writing. As described in the paper Meneses and Furuta [2015], writers enter the poem, receive a visualization and can control this visualization with body and hand gestures which in turn influence the poem. By such interconnection author aims to make Ambiances a part of the writing process and give it a chance to influence the final result. However the actual software does not seem to be openly available.

1.3 Generation tools

Lau et al. [2018] - learns rhyme automatically, for sonnets, results indistinguishable, apart from expert evaluation, missing emotion

[6] http://www.sci.utah.edu/ nmccurdy/Poemage/

2. About data

3. Lyrics evaluation

3.1 Rhyme detection

3.1.1 Pronunciation

Unlike many other languages, English does not have a straight forward pronunciation rules. Therefore to be able to assess rhymes, we need to transcribe our text into a phonetic alphabet first. There are two commonly used alphabets to choose from - IPA and ARPAbet. The original International Phonetic Alphabet (IPA) used since 1888 uses one UNICODE character to encode each phoneme and it is commonly used for example in dictionaries. Since it uses non-ASCII characters, ARPAbet was developed as an equivalent for computers. It has two versions: 1-character that uses upper-case and lower-case letters and 2-character version where each phoneme is represented by one or more upper-case ASCII characters (Klautau [2001])(see Table3.1 for comparison). We will be using 2-character ARPAbet because it is used by CMU dictionary.

Example word	IPA	1-character ARPAbet	2-character ARPAbet
st**o**ry	ɔ	c	AO
bu**tt**er	ɾ	F	DX

Table 3.1: Comparison of different pronunciation alphabets.

Carnegie Mellon University Pronouncing Dictionary (CMUdict) is an open-source pronunciation dictionary.[1] Currently it contains 134,373 words (including their inflections) and their pronunciations in 2-character ARPAbet. For each word there is one or several possible pronunciations in North American English including stress markers for primary, secondary or no stress. For the implementation we used its python wrapper package *cmudict* [2]. To use this we need to strip the input of punctuation and convert it to lower case.

This is a large dictionary and it includes also slang words so it should cover most of our input. To test this, we looked at all last words on each line of our data (since those are the important ones for rhyme analysis) and we found out that 5.52% of them are not in CMU dictionary. These included:

- uncommon words, e.g. superglue, redundantly
- misspelled words, e.g. decsion, girlfren
- numbers
- foreign words, e.g. revoluccion, ecolli
- interjections and onomatopoeia, e.g. shoooshooo, woahwoah

Describe here how we dealt with the ones not in CMUdict.

[1] http://www.speech.cs.cmu.edu/cgi-bin/cmudict
[2] https://pypi.org/project/cmudict/

3.1.2 Syllabification

Once we have the pronunciations we can start to compare them. When comparing lines for rhymes we have to establish a system of alignment so that we analyze only relevant pairs of phonemes. Initially, we created a simple rhyme detector that just traversed both verses backwards phoneme by phoneme and compared them. However, rhyming words don't have to have an equal number of phonemes. For example words in the Table 3.2 have a 2-syllable rhyme. However if we compared each phonemes one by one they get misaligned on consonant clusters S-T-R and P-L and we will miss the second syllable rhyme.

Word	ARPAbet transcription
constrain	K AH N - S T R EY N
complain	K AH M - P L EY N

Table 3.2: Example of misalignment when aligning by phonemes.

We need to make sure that we are comparing corresponding parts of verses otherwise we will miss the rhyme. A better approach would be to compare corresponding syllables. Each syllable can be further split into 3 groups ("CVC") - leading consonant cluster, vowel, and trailing consonant cluster. Consonant clusters can sometimes be empty. For syllabification we used python library *syllabify* [3] which conveniently returns syllables in CVC triplets as described above.

3.1.3 Rhyme types and literary devices

Although everyone instinctively knows what a rhyme is and can recognize one in a poem or a song, it does not have a very precise definition. It is described as "a word that has the same last sound as another word" by Cambridge Dictionary (Walter [2008]) or a "literary device, featured particularly in poetry, in which identical or similar concluding syllables in different words are repeated" by LiteraryDevices Editors [2020]. These definitions are not detailed enough to base a good algorithm off of, so let's look deeper into different rhyme types.

Perfect rhyme (also true rhyme, or sometimes just "rhyme") is the most common and valued type of rhyme. It requires two conditions to be met: cite?

- last stressed vowel and all following sounds are identical
- immediately preceding sounds differ

It is also the only rhyme for which the definitions are consistent (for example, see Bain [1867], van der Schelde [2020], Bergman [2017], [4]). It can be further distinguished depending on how many syllables are involved:

- **Masculine** (also single, monosyllabic) - "the commonest kind of rhyme, between single stressed syllables at the ends of verse" (Baldick [2008]). Examples:

[3] https://github.com/kylebgorman/syllabify
[4] https://en.wikipedia.org/wiki/Rhyme

fly (flaɪ) / sky (skaɪ)

before (bi-fɔr) / explore (ɪks-plɔr) [5] [6]

- **Feminine** (also double) - "a rhyme on two syllables, the first stressed and the second unstressed" (Baldick [2008]). Examples:

  bitten (bɪ-tən) / written (rɪ-tən)

  lazy (leɪ-zi) / crazy (kreɪ-zi)

- **Dactylic** (also triple) - "a rhyme on three syllables, the first stressed and the others unstressed"(Baldick [2008]). Examples:

  amorous (æ-mər-əs) / glamorous (glæ-mər-əs)

  vanity (væ-nɪ-ti) / humanity (ju-mæ-nɪ-ti))

Imperfect rhyme (also slant or half rhyme) rhymes "the stressed syllable of one word with the unstressed syllable of another word" (Bergman [2017]). Examples:

cabbage (kæ-bɪdʒ) / ridge (rɪdʒ)

painting (peɪ-nɪŋ) / ring (rɪŋ)

In other sources, definitions differ - for example LiteraryDevices Editors [2020] calls this effect "feminine rhyme". On the other hand, Baldick [2008] and The Editors of Encyclopaedia Britannica [2014] use the term "imperfect rhyme" for end-line consonance (see definition below) and van der Schelde [2020] uses it for end-line assonance (see definition below). For the purpose of this thesis we will work with the first definition mentioned.

Unaccented rhyme (also weakened rhyme) "occurs when the relevant syllable of the rhyming word is unstressed" (The Editors of Encyclopaedia Britannica [2014]). Examples:

hammer (hæ-mər) / carpenter (kɑr-pən-tər)

The difference opposed to imperfect rhyme is that here both rhyme fellows are unstressed.

Identical rhyme (also rime riche) is "a kind of rhyme in which the rhyming elements include matching consonants before the stressed vowel sounds." This includes "rhyming of two words with the same sound and sometimes the same spelling but different meanings e.g seen (sin)/ scene (sin). The term also covers word-endings where the consonant preceding the stressed vowel sound is the same: compare (kəm-pɛr) / despair (dɪ-spɛr)." (Baldick [2008]). It is generally considered not as good as perfect rhyme because it is too predictable for the listener[7].

[5] For the examples, we are using IPA transcriptions because it's more comfortable for human reader.

[6] Stressed syllables are underlined. Syllables are separated with a hyphen.

[7] https://literaryterms.net/rhyme/

Forced rhyme (also near rhyme) "includes words with a close but imperfect match in sound in the final syllables" Bergman [2017]. Examples:

green (grin) / fiend (find)

hide (haɪd) / mind (maɪnd)

This includes the case when spelling in changed in order to make the rhyme work, e.g. truth (truθ) / endu'th (en-duθ) (a contraction of "endureth"). It can also refer to using unnatural word order to get the rhyming word at the end of the line (Bergman [2017]) but we will not make use of this interpretation in this thesis.

Assonance is "repetition of stressed vowel sounds within words with different end consonants" (The Editors of Encyclopaedia Britannica [2014]). Examples:

quite (kwaɪt) / like (laɪk)

free (fri) / breeze (briz)

The term itself defines a literary device applicable anywhere in the poem but when used at the end of verse, it can sometimes be considered a rhyme (under various names) by sources like van der Schelde [2020], Bergman [2017] and others.

Consonance is "the recurrence or repetition of identical or similar consonants" (The Editors of Encyclopaedia Britannica [2014]). Examples:

country (kən-tri) / contra (kɑn-trə)

hickory dickory dock (hɪ-kə-ri dɪ-kə-ri dɑk)

Similarly as assonance, it applies to repetition anywhere. When seen at the end of verse, it can be considered a rhyme and again, various terms are used, perhaps the most common is "pararhyme" (The Editors of Encyclopaedia Britannica [2014], Baldick [2008]).

The last two terms may seem as more of a tool for poets than songwriters. Surprisingly, they have found their way into song lyrics and have become a standard in genres like hip hop according to van der Schelde [2020]. From the creative point of view, it is not less sophisticated rather it enriches rhyme as we know it (Brogan [2016]).

Mention here we're not using it as a rhyme - or maybe if it will be highlighted in the visualization?

Other rhyme types exist e.g. eye rhyme where "the spellings of the rhyming elements match, but the sounds do not, e.g. love (ləv) / prove (pruv)" (Baldick [2008]). We will be omitting them because we did not consider them relevant for song lyrics or the purpose of this thesis.

Not sure how to connect this with the rest. Maybe it will fit more with the website demo or final statistical rhyme analysis of the dataset.

3.1.4 Calculating rating for one rhyme

Finally, we have extracted pronunciation and syllables so we can continue to analyze the rhyme and rate the song. We decided to first calculate ratings for pairs of verses and then create an overall song rating based on these individual ratings. Another approach would be to analyze the complex statistics of the entire song and rate it at the end all at once. The second method could be better

at incorporating the high-level properties like repeating of the refrain. We chose the first approach because it is more straight-forward and gives us a number for each rhyme which can be more interesting for the writer. Additional high-level analysis can be added later if necessary.

So let's focus on the rhyme analysis of two verses - or rhyme fellows - as they are typically called. Rhymes are located at the end of each line so there is no need to analyze the entire verse. How far should we look? The first choice would be to look at the last word. However rhymes can extend over more words as we see in

Find an example of multi-word rhyme where the second word is unaccented

. When we look at the rhyme types, the basic ones don't go further then the first stressed syllable (looking at the line backwards). Notably, even if the rhyme does extend further we can ignore the rest because it will not contribute to the rating. According to our research, the most perfect rhyme is perfect rhyme so it should get the perfect score. And if there are more rhyming syllables preceding the perfect rhyme, they cannot make the score better. Similarly, if the rhyme isn't perfect, syllables preceding the final stress would already be considered an internal rhyme - which is also used (mainly in rap lyrics) but less valued than the classical end rhyme. We will therefore limit our window to the minimum number of syllables needed to include the stressed syllable in both rhyme fellows. Having a sequence of four unstressed syllables is very unlikely in English language so we limited our word preprocessing (pronunciation + syllabification) to last 4 syllables to speed up the performance.

To determine the rhyme we need to assess the match in sound of individual phonemes. Since we have each syllable separated into three groups we decided to give each group a number between -1 and 1 that would represent how similarly they sound. The numbers are assigned according to following heuristic:

Rewrite this list in a better-readable manner.

- 1 - all phonemes are identical
- 0.75
  - one is a subset of another
  - it's a pair of similar sounding phonemes
- A number between 0 and 1 if both are consonant clusters. This number is calculated:
  1. Add 1/(length of the shorter consonant cluster) for each **shared** sound at the beginning or the end of the consonant clusters.
  2. Add 0.75/(length of the shorter consonant cluster) for each **similar** sound at the beginning or the end of the consonant clusters.
- 0 - both are empty
- -0.5 - one of them is empty
- -1 - otherwise, meaning no matching or similar sounds

1^{st} verse	on	her	front	door
2^{nd} verse	can't	stand	no	more
1^{st} pronunciation	_, AA, N	HH, ER, _	F R, AH, N T	D, AO, R
2^{nd} pronunciation	DH, AH, _	P, EY, N	N, OW, _	M, AO, R
similarity	-0.5, 0.75, -0.5	-1, -1, -0.5	-1, -1, -0.5	-1, 1, 1

Table 3.3: Example similarity evaluation for the last 4 syllables of two verses from song Cheatin' Woman by Lynyrd Skynyrd.

For an example of similarity evaluation see Table 3.3.

To identify similar sounds, we look them up if there is a similarity group containing both of them. These similarity groups were created...

Describe how it was done. The iterative appraoch? Or maybe Holtman's hierarchy?

Words for which we haven't found pronunciation cannot be further processed so they are given rhyme rating 0 and skipped. Some words may have multiple possible pronunciations - in that case we evaluate each possible combination of pronunciations for given line pair. After we assign a rating for each combination, we will keep only the best rated combination of pronunciations and discard the rest.

With these similarity values we can proceed to calculate the rating which we decided to be as typically between 0 and 1. We will look at it syllable by syllable a return an average. There are some cases we need to consider individually:

- different - if all similarities are equal to -1, we can definitely say they don't rhyme and return a rating of 0
- identical - since identity is a weaker rhyme than perfect, it will be given a penalty for "little creativity" returning a fixed rating of 0.8
- perfect - perfect rhyme has a specific structure and if that holds, we can return the perfect score of 1.0

For the remaining cases we will create rules based on how rhymes behave. Not all phonemes are equally important so let's assign weights to reflect it. The key role in rhyming plays the vowel so it should have the strongest impact on the rating. Second important is the ending consonant because it's closer to the end. Beginning consonant can add up to a nicer rhyme but it cannot bear the rhyme on its own. Since the vowel itself can be enough to create the rhyming effect it should have more weight than the rest combined. Therefore we assigned weights as follows:

Beginning consonants: 1, Vowel: 4, Ending consonants: 2

The rating for one syllable is created as normalized sum of weights times similarities. Furthermore, we need to account for stress. We can do that by multiplying the result with a multiplication factor depending on how does the stress match.

- 1.0 for stressed rhyme because it is the strongest

- 0.9 for unstressed rhyme - it's weaker but the stress pattern matches
- 0.8 for an mismatching stress pattern

The final formula for a rhyme rating is an average of syllable ratings and looks like this:

$$average(stress\_multiplication\_factor * weighted\_average(similarities))$$

This formula formatting looks weird but I don't have an idea how to do it better.

3.1.5 Calculating song rating

The next step is to combine these rhyme ratings into one final rating for the entire song.

- ako z toho spocitat rating pre celu pesnicku - vramci toho aj rhyme scheme
- nejaky priklad ratingu pre pesnicku
- pocitanie slabik + ako odhadujem slabiky ked nemam ARPAbet transcription - k tomu by asi bola dobra nejaka statistika ze nam to k niecomu pomohlo

Conclusion

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List of Figures

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[9] https://sourceforge.net/projects/prosevis/

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List of Abbreviations

A. Attachments

A.1 First Attachment