

# The Use of Multi-Step Markov Chains in the Characterization of English Literary Works

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**Abstract**—Typical English literary works tend to include a wide variety of different dimensions and features, and these would constitute the apparatuses which enable individual authors to express their personal sentiments and perspectives in different eras and cultural settings. We make use of iambic pentameter to quantify and characterize such dimensions by the use of Markov chains. Here, we adopt a machine learning approach by processing and extracting the characteristics of known passages and ultimately represent these as a signature transition matrix. We develop a multi-step Markov chain to characterize the time evolution of stress levels. In this approach, arbitrary amount of memory on previous stress levels may be incorporated into the model. It is expected that this method may be further developed and leveraged to enhance understanding and appreciation of English literary works, which will eliminate the application of subjective human judgments.

**Keywords** - English literature; Markov model; Multi-step Markov chain; Shakespearean plays; sparse matrix.

## I. INTRODUCTION

The richness of literary passages possesses multi-faceted characteristics, and such characteristics would allow different authors to express their unique emotions and outlook in different periods of time and cultural environments. In computational literary analysis, differing aims include determining authorship, sentiments, emotional contents, outlook, motif, rhythm, metre and purpose. Due to the complex dimensions, features and genres in English literature, there remain two especially significant obstacles in computer-aided literary attribution, respectively, practical and philosophical, which are related [7].

As literary works can be viewed from a machine learning perspective [8]-[12], we first introduce a one-step Markov chain where the future stress level is dependent only on the present one. While this is useful, its limitation being that it is largely memoryless and ignore earlier stress levels. To overcome this restriction, we develop a multi-step Markov chain to characterize the evolution of stress levels. Through the combined use of one-step and multi-step Markov chain, show that certain characteristics of these works remain fairly uniform.. The examples include polarity of emotions, average sentence length, the arrangement of words, the occurrences of a particular word and punctuations.

We use machine learning approaches to learn the characteristics of known passages using big data and ultimately encode these as a signature. In these approaches, arbitrary amount of memory on previous stress levels may be incorporated, with the caveat that the number of possible states would grow exponentially. By exploiting such sparsity, we are able to generate a numerical signature to characterize a passage.

We also improve the traditional way of manually using human judgments to analyze literature into a faster and more space-efficient one.

The rest of this paper is organized as follows. The next section, with the help of specific examples, gives the motivation of studying English literary works by using Markov chains as a first approximation. As a second approximation, since the simple Markov chain is limited in memory of the past, the multi-step Markov chain is developed in Section III, which is followed by experimentations in Section IV. The paper concludes in Section V.

## II. A MARKOV CHAIN CHARACTERIZATION

Poems in one sense may be viewed as apparatus for the expression of human sentiments and emotions which are often manifested and closely intertwined in the poetic structure, metre, and rhyme scheme. To fix ideas, we consider Wordsworth's poem "Daffodils" by first examining its emotional elements, and then consider the poetic structure.

Daffodils are usually the symbol of "physically weak or impotent" [14] in English literature, and the lexical "daffodils" is a dactyl trisyllable with a stress on the first syllable. In the poems and a journal entry "Daffodils" [17]-[19], Ted Hughes, William Wordsworth, and Dorothy Wordsworth present the traits of daffodils by employing various rhetorical patterns and linguistic features. The characters can think and feel. European romanticism claims it is a new model of presence and emphasizes centrality [15]. The characters' feelings and emotions could be related to Zen's paradoxical philosophy of "fullness and emptiness" because 'up comes to a flower and a world is born' [16]. This "fullness and emptiness" philosophy is like the waxing and the waning of the Moon. It shows how the characters see the "happiness and sadness" and "fullness and emptiness" in their space time. Through the eyes of the characters, it could also bridge the gap between the sentiment lexicon analysis and the cross-cultural interpretation of literary works.

TABLE 1. POLARITY AND EMOTIONS

Polarity	Verse	Emotion
Positive	Tossing their heads in sprightly dance	Sprightly
	A poet could not but be gay	Gay
	In such a jocund company	Jocund
Negative	Which is the bliss of solitude	Bliss; Solitude
	I wandered lonely as a cloud	Lonely
	In vacant or in pensive mood	Vacant; Pensive

a. "Daffodils" by William Wordsworth [17]

From a language aspect, among the 24 lines (153 words) in William Wordsworth’s poem “Daffodils”, there are nine emotional lexicons, which are further tagged as “positive” or “negative”. The five positive words include “sprightly, gay, jocund, bliss, and pleasure”, which are the similar expression of “happiness” but with different degrees of “happiness”. The varying degree of “happiness” could be the interpretation of Zen’s “fullness” in eastern culture. In contrast, the four negatives are “lonely, vacant, pensive, and solitude”, which represent the paradoxical pair of “sadness” or Zen’s “emptiness”. The same method is applied to the analysis of Ted Hughes’ poem “Daffodils” and Dorothy Wordsworth’s journal entry of “Daffodils”. Hughes’ poem [18] has three explicit emotions: eagerness, happiness, death, and being overwhelmed. In Dorothy Wordsworth’s journal entry [19], the positive emotion lexicons of the characters are “fancied, laughed, gay, good, enjoyed”, whereas the negatives are “cheerless” and “sour”. In these English literary pieces, the emotions are the paradoxical pair of “happiness and sadness” and its varying degree of “fullness and emptiness”.

In English literary writings, iambic pentameter plays a key role. In particular, one of the most important aspects of Shakespeare’s language is his use of stress, the way certain syllables are emphasized in words more than others. In a line of a poem, a foot is a certain number of stressed and unstressed syllables, forming distinct units, as a musical measure consists of a certain number of beats. Delimitation of the sounds of the spoken chain can be based on auditory impressions, but the description of these sounds is an entirely different process. Description can be carried out on the basis of the articulatory act, for it is impossible to analyze the units of sound in their own chain [2].

Stressed syllables vary in strength, while unstressed syllables vary in weakness; and a third group can strike us as uncertain as falling into a range that seems stronger than unstressed but weaker than stressed [2]. Therefore, it is common to notate the stressed sound with a “/” marking ictic syllables and a “x” marking nonictic syllables. In this notation, a standard line of iambic pentameter would look like, “x / x / x / x / /” where each line of verse is made up of five two-syllable iambs for a total of ten syllables. This is used for many of Shakespeare’s most famous lines. As the metre is mainly about sound, not spelling, scansion adds numbers to indicate a variety of stress levels to realize beats and offbeats (1=lightest stress, 4=heaviest stress).

In relation to the poetic structure, metre and rhyme scheme, William Wordsworth’s poem “Daffodils” [17] also exhibits correspondence with “fullness and emptiness”. Here, the stressed sounds are in bold and labelled as “/”, whereas the unstressed sounds are marked as “u”.

u / u / u / u /

*They flash upon that inward eye*

u / u / u / u /

*Which is the bliss of solitude;*

u / u / u / u /

*And then my heart with pleasure fills,*

u / u / u / u /

*And dances with the daffodils.*

b. “Daffodils” by William Wordsworth [17]

### III. MULTI-STEP MARKOV CHAIN CHARACTERIZATION WITH MEMORY

In the above, if we break down the unstressed groupings, then a one-step Markov chain will not be adequate as the situation retains a certain amount of memory. More precisely, it remembers how many unstressed metres occurred in the past before it can determine whether the next one should be stressed or unstressed: if the past three metres were all unstressed, then the next one should be stressed; if the past three metres were not all unstressed, then the next one should be unstressed. Thus, knowing only the current state will not be able to predict what happens next.

Hence, to remove the limitations on the above simple model, we can proceed in two directions: we can increase the number of possible states; and to reduce the memoryless property in the Markov chain. Let us initially concentrate on the first direction as Markov model recognition systems can effectively be realized for classification systems at large scales [1]

Consider Part I of Shakespeare’s play “King Henry the Sixth”, where the rebel Jack Cade beheads a lord for printing books and setting up a grammar school to teach young men to read instead of leaving them to tally their business accounts, we have

1 4 1 4 1 4 1 3 1 4  
x / x / x / x / x /

*His brandisht Sword did blinde men with his beames.*

c. The Sonnets [13]

The transition matrix of the above line, where the four states indicate the stress levels of 1, 2, 3, 4 respectively, is

$$\begin{pmatrix} 0 & 0 & 0.2 & 0.8 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

It is possible to perform a simplification of this enhancement from the following observation. While the English syllables we speak can be spoken with many degrees or shades of emphasis of loudness, sharpness, duration, and other ways of signaling importance, it seems likely that in most English speech we perceive mainly two major levels of stress, and that we hear a continuous series of relatively stressed and relatively unstressed syllables [2]. Hence, the following

1 4 1 4 1 4 1 4 1 4  
x / x / x / x / x /  
*His sparkling eyes, repleat with wrathfull fire.*

d. The Sonnets [13]

can be constructed simply as

$$\begin{pmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

using binary entries for the transition matrix.

Assuming these come from the same piece of work, and if the first pattern occurs with probability  $r$ ; and the second pattern

occurs with probability  $s$ , and that there are no other patterns, then we have the following combined transition matrix  $T$

$$T = r \begin{pmatrix} 0 & 0 & 0.2 & 0.8 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix} + s \begin{pmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

which results in the transition matrix

$$T = \begin{pmatrix} 0 & 0 & 0.2r & 0.8r + s \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

Such a transition matrix may be used to characterize authorship.

As suggested by Cheney Patrick [5], a laureate entitled *counter-authorship* is a form of authorship that exists not in isolation but also in reaction, and when we profitably speak of Shakespeare, another laureate has been phrased as *counter-lauréate authorship* [5]. One example of the *counter-lauréate authorship* in “King Henry the Fourth” as following is pivotal in the action of the play because it is first verification that the character Hal is in the process of reforming from tavern wastrel to national hero.

0 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
*Wanton as youthful goats, wild as young bulls.*

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
*I saw young Harry with his beaver on,*

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
*His cushes on his thighs, gallantly arm'd,*

1 4 1 4 1 4 1 4 1 3  
 × / × / × / × / × /  
*Rise from the ground like feathered Mercury,*

1 4 1 3 1 4 1 4 1 4  
 × / × / × / × / × /  
*And Vaulted with such ease onto his seat*

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
*As if an angel dropp'd down from the clouds*

1 4 1 4 1 4 1 4 1 3  
 × / × / × / × / × /  
*To turn and wind a fiery Pegasus,*

1 4 1 4 1 4 1 4 1 3  
 × / × / × / × / × /  
*And witch the world with noble horsemanship.*

e. Henry IV, Act I, 103-110 [3]

The above passage, disregarding the first line, may be characterized by the following transition matrix

$$\begin{pmatrix} 0 & 0.03 & 0.11 & 0.86 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

Another form of *counter-lauréate authorship* emerges in a more obvious place, Theseus’s speech in the mid-1590s romantic comedy “A Midsummer Night’s Dream”. It is noticeable that Shakespeare’s self-reflexive revision, such as the inserting discourse about the ‘poet’ as company for “lunatic” and the “lover”, turns a speech about the madness of love into one about the poet’s role in forming an eternizing state of consciousness [5].

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
 More **strange than true**. I **never** may believe

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
 These **antic fables**, **nor** these **fairly toys**.

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
 Lovers and **madmen** have **such seething brains**,

1 4 1 4  
 × / × /  
 Such shaping **fantasies**, that **apprehend**

1 4 1 4 1 4  
 × / × / × /  
 More **than cool reason** ever **comprehends**

1 4 1 4 1 4  
 × / × / × /  
 The **lunatic**, the **lover**, and the **poet**

1 4 1 4  
 × / × /  
 Are of **imagination** all **compact**.

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
 One **sees** more **devils** than vast **hell** can **hold**;

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
 That **is** the **madman**. The **lover**, **all** as **frantic**,

1 4 1 4 1 4 1 4  
 × / × / × / × /  
 Sees **Helen’s beauty** in a **brow** of **Egypt**.

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
 The **poet’s eye**, in a **fine frenzy rolling**,

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /  
 Doth **glance** from **heaven** to **earth**, from **earth** to **heaven**;

1 4 1 4 1 4 1 4  
 × / × / × / × /  
 And as **imagination** **bodies forth**

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /

The forms of things unknown, the poet's pen

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /

Turns them to shapes, and gives to aery nothing

1 4 1 4 1 4  
 × / × / × /

A local habitation and a name.

1 4 1 4 1 4  
 × / × / × /

Such tricks hath strong imagination,

1 4 1 4 1 4 1 4  
 × / × / × / × /

That if it would but apprehend some joy,

1 4 1 4 1 4  
 × / × / × /

It comprehends some bringer of that joy;

1 4 1 4 1 4  
 × / × / × /

Or in the night, imagining some fear,

1 4 1 4 1 4 1 4 1 4  
 × / × / × / × / × /

How easy is a bush suppos'd a bear?

f. A Midsummer Night's Dream, Act V, Scene I, 2-22 [3]

The above passage may be characterized by the following matrix

$$\begin{pmatrix} 0 & 0 & 0 & 1 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \end{pmatrix}$$

In general, the transition matrix  $U$  for a given piece of literary work may be represented as, assuming there are  $m$  patterns, each occurring with probability  $p_i$ ,

$$U = \sum_{j=1}^m p_j T_j$$

where each  $T_j$  corresponds to the characteristic matrix of pattern  $j$ .

Thus, with vast text collections, Markov matrices can be systematically built and it provides a unique characterization of each period and author and nature of work.

In the above, a one-step Markov chain is used, but in more general situations, as pointed out above, a multi-step Markov chain (with a longer past memory chain) is required. Let us consider the following fragment from "King Henry the Fourth",

1 4 1 4 1 4 1 4 1 2  
 × / × / × / × / × /

His cushions on his thighs, gallantly arm'd,

1 4 1 4 1 4 1 4 1 3  
 × / × / × / × / × /

Rise from the ground like feathered Mercury,

1 4 1 3 1 4 1 4 1 4  
 × / × / × / × / × /

And Vaulted with such ease onto his seat

We see here that state 1 does not always make a transition to state 4; it sometimes goes to state 2 and sometimes go to state 1. In fact, it retains memory of the past states in addition to the current state.

Let us amalgamate two consecutive states into one single state, thereby injecting more memory into the chain. In doing so, we incorporate memory of the immediate past state as well as the current state to determine the future transition. Thus, from the primitive states of  $S = \{1, 2, 3, 4\}$ , we now have the new set of states  $\Omega$ ,

$$\begin{aligned} \Omega = S \times S = \{ & (1, 1), (1, 2), (1, 3), (1, 4), \\ & (2, 1), (2, 2), (2, 3), (2, 4), \\ & (3, 1), (3, 2), (3, 3), (3, 4), \\ & (4, 1), (4, 2), (4, 3), (4, 4) \}, \end{aligned}$$

with  $|\Omega| = 16$ . Thus, by including memory of the past state, we can construct a  $16 \times 16$  transition matrix.

For the above situation, let us reduce the number of states and omit those that do not occur as follows,

$$\begin{aligned} \Omega = S \times S = \{ & (\overline{1,1}), (1, 2), (1, 3), (1, 4), \\ & (2, 1), (\overline{2,2}), (\overline{2,3}), (\overline{2,4}), \\ & (3, 1), (\overline{3,2}), (\overline{3,3}), (\overline{3,4}), \\ & (4, 1), (\overline{4,2}), (\overline{4,3}), (\overline{4,4}) \}. \end{aligned}$$

Doing so will reduce the number of states from 16 to 6, with the reduced set of states  $\Omega'$  as,

$$\Omega' = \{ (1, 2), (1, 3), (1, 4), (2, 1), (3, 1), (4, 1) \}.$$

By considering the frequency of occurrence, we obtain the following signature transition matrix, where the states are ordered according to the above sequence of  $\Omega'$ ,

$$H' = \begin{pmatrix} 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 0 & 0 \\ 0.09 & 0.18 & 0.73 & 0 & 0 & 0 \end{pmatrix}$$

In general, if  $|S| = n$ , this will result in a  $n^2 \times n^2$  matrix before any reduction. The form and values of the entries in the matrix may be regarded as a characteristic signature of the passage in question, and we also note that such a matrix tends to be a sparse matrix.

Admittedly, the determination of transition probabilities, especially for extended memory situations, can be quite laborious. Other less computationally intensive methods exist, however, such as measuring the number of different types of lines, such as interrogative lines or exclamatory lines. A recommended procedure is to apply these less computationally intensive methods first, and then for fine tuning, apply the signature method above for greater accuracy.

IV. EXPERIMENTATION

Here, we examine and analyze Shakespeare’s work “Henry VI” and focus on his use of interrogative and exclamatory lines because it is rare to always identify the extent of a particular writer’s work beyond a significant margin of error [6]. From our analysis of the passage, the results are plotted in Figures 1 and 2.

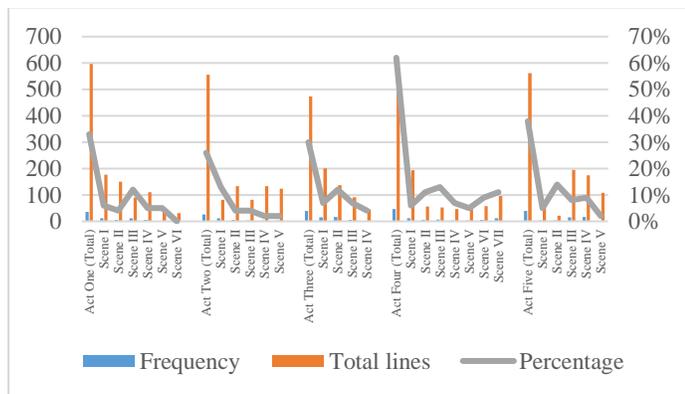


Figure 1. Exclamatory lines in Henry VI, Part I

It would be uneasy with the claim that Shakespeare wrote nothing in Part One [4], because from Figure 1, it is noticeable that Acts One, Two, Three and Five share relatively a stable 30% of using exclamatory lines, and the frequencies are roughly lower than 39, whereas in Act Four the figure largely varies from the previous ones, reaching the highest 62% and standing a figure of 47 in frequency.

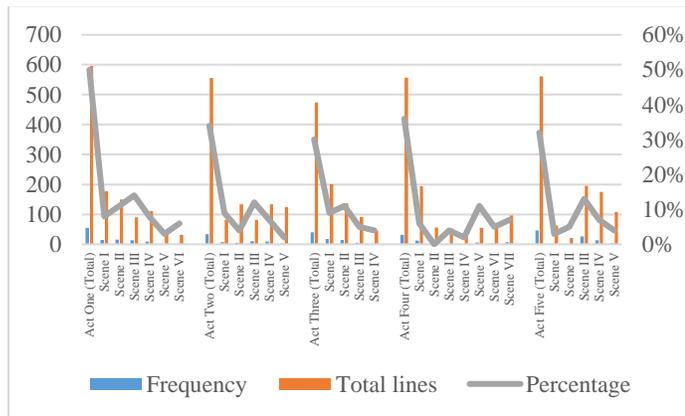


Figure 2. Interrogative lines in Henry VI, Part I

As for Figure 2, the interrogative lines in Acts Two, Three, Four and Five perform consistently at an average of 33% and a frequency of approximately 38, while Act One rises to 50% at 55 in frequency.

From these results, it is clear that Acts Two, Three and Five succeeded in maintaining the stability of the frequency in utilizing both the exclamatory and interrogative lines. In short, Part One’s inclusion cannot be taken as evidence of Shakespeare’s sole authorship [4], and conjunction of historical and analytical evidence suggests that it might be collaborative. Furthermore, Act One and Four contain indication regarding the collaboration of other authors as the analyzed data “betrayed” the works that bear Shakespeare’s name. If Part One postdates its two companions, then the primitive style of most of it can hardly be attributed to Shakespeare, and the “trilogy” is an

artistic afterthought, not the product of the aspiring vision of a young prodigal genius [4].

V. CONCLUSION

English literary works tend to include many dimensions and features, and these would constitute the apparatuses that enable different authors to express and articulate their personal sentiments and perspectives in different eras and emotional settings. In the analysis of literary works, there are differing aims, which include determining such aspects as the authorship, the emotional contents, sentiments, outlook, motif and purpose. We have made use of iambic pentametre to quantify and characterize such dimensions by the use of Markov chains.

In place of using human judgments, which is largely a manual process and a time-consuming process, we have proposed the use of a machine learning approach by learning the characteristics of known passages using big data and ultimately encode these as a signature. We first introduce a one-step Markov chain where the future stress level is dependent only on the present one. While this is useful, its limitation being that it is largely memoryless and ignores earlier stress levels. To overcome this restriction, we develop a multi-step Markov chain to characterize the evolution of stress levels. In this approach, arbitrary amount of memory on previous stress levels may be incorporated, However, a caveat concerning this method is that by extending the memory too far into the past may lead to overfitting in some situations which makes it sometimes difficult to effectively generalize. It is recommended that the memory extension should not be more than four steps.

The present method is able to significantly eliminate error-prone and relatively subjective human elements, and it is expected that this approach may be further developed and leveraged to enhance understanding and appreciation of English literary works.

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