Rhythm and Vocabulary of Greek Hexameter: From Formula to Topolexis

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Abstract

The article discusses the results of our application of a computer program created for the automatic analysis of lexical distribution based on rhythmic position in Greek hexameter.

For this purpose, we introduce the concept of the topolexis (in Greek τοπολέξις: from τόπος "place" and λέξις "expression, word"), which describes each word based on its position in the given line and is expressed as the word in combination with two sets of numerals. The topolexis "52Ἀχιλῆος62", for example, indicates that the word Ἀχιλῆος begins at the second syllable of the fifth foot (52) and ends at the second syllable of the sixth foot (62).

We investigate the behavior of topolexes in a corpus that includes Homer's *The Iliad* and *The Odyssey* and Apollonius Rhodius' *The Argonautica*. We find that the distribution of topolexes of different frequencies varies among these texts. While *The Argonautica* contains a greater number of unique topolexes, higher-frequency topolexes are more common in Homer's poems. The "formulaicity ratio", which we define as the ratio of distinct topolexes in a text to its overall topolexis count, is higher for Homer. In addition, we obtain and analyze data about Hesiod's *The Theogony*. Although *The Theogony* is only 1,023 lines long, it exhibits the same tendencies as Homeric hexameter. We are, thus, able to clearly and accurately compare the behavior of topolexes in epic hexameter in the formulaic style and in its literary imitation by Apollonius.

Lastly, we run a test to compare the performances of the topolexes and the most frequent words (MFW) as stylometric indicators for determining text authorship. We find that while topolexes enable us to correctly cluster fragments by their author, they do not outperform the MFW in this respect.

1   Introduction

The present study is devoted to the relationship between rhythm and vocabulary in verse, or more specifically, the organization of linguistic material within the poetic line.[1] Our methodology is inspired by two research streams, of which one stems from work on verse syntax, which has been advancing in Russian verse studies since the 1920s, while the other is based on the oral-formulaic theory that originated with Milman Parry and Albert Lord's work on Homeric and other epic traditions.

The first of these two inspirations refers particularly to Osip Brik's work. In his pioneering study, "Ritm i sintaksis" (Rhythm and Syntax) (1927/2012), Brik pointed out that poetic speech reflects a dynamic interaction of rhythm, syntax, and semantics. He saw the most conspicuous display of this interaction in what he termed "rhythmic-syntactic clichés (formulae)": "A poetic cliché is precisely the result of a complete fusion of the rhythmic, syntactic, and semantic aspects of the poetic word [whereby] conventional word combinations are formed in [terms of] which the poet himself thinks" (Brik 2012, p. 520). Brik's ideas have been fruitfully developed by Russian verse scholars over the last century. Mikhail Gasparov's contribution is especially significant in this respect: drawing on Brik's and Boris Yarkho's ideas, Gasparov succeeded in creating a linguistically substantiated method, which he used to analyze a wealth of material.[2] In particular, he claimed that "(a) a *rhythmic cliché* is a fixed sequence of rhythmic words (which in verse studies is referred to as *word boundary line variation* [словораздельная вариация] [...]; (b) a *syntactic cliché* is a recurring sequence of the same phrase/sentence constituents [...]; (c) a *rhythmic-syntactic cliché* is a combination of both [(a) and (b)] [...]; (d) a *rhythmic-syntactic formula* is a rhythmic-syntactic cliché involving the exact recurrence of one or more words" (Gasparov 1986, p. 189).

Gasparov's associates and followers have enhanced his methods and applied them to different poetic material in recent decades. In this way, they have also developed his theories about the relationship between rhythm and syntax (Akimova 2017a; Belousova et al. 2019; Kruglova et al. 2019; Tarlinskaja 2015; Tverianovich 2019).

The second methodological tradition that we draw on arose from the study of what are known as Homeric formulae. Parry and Lord set out to demonstrate that *The Iliad* and *The Odyssey* were, in fact, instances of oral poetry and that these formulae played a special role in the two texts. In this context, Parry defined a formula as "*une expression qui est régulièrement employée, dans les mêmes conditions métriques, pour exprimer une certaine idée essentielle*"[3] (Parry 1928, p. 16; Lord 1960; Parry 1971).[4] Curiously, Parry, like Brik, linked vocabulary, rhythm, and semantics together. In the years since, classical philologists and specialists in other types of epic have made copious and often extremely

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[1] The authors wish to thank the editors and anonymous reviewers of this volume for their insightful comments and suggestions.

[2] Concerning Brik, Yarkho, Gasparov, and the history of the study of verse syntax, see Akimova 2012, 2015, 2017b, including an extensive bibliography; see also Tver' yanovich 2008, pp. 110–114.

[3] "an expression regularly used under the same metrical conditions to express an essential idea".

[4] For a discussion of and amendments to this definition and related amendments, see Nagy 1990.

productive efforts to apply the oral-formulaic theory to texts from various poetic traditions (see Foley 1985).

Predictably the advent of computer tools has also prompted an ever-increasing number of statistical analyses of the formulaic style. In the second edition of his influential book on *The Iliad*, Martin Mueller, thus, added an entire chapter called "Homeric Repetitions" (2009, pp. 135–172) which used statistics to describe the workings of recurring elements in the Homeric epic. More recently, Sklaviadis et al. (2019) have completed a similar study that uses n-gram analysis and independently confirms Mueller's findings. This work also examines recurrences in relation to their linear location by identifying the positions within hexameter verse where n-grams recur most often (2019, p. 243 Fig. 4).

The current study continues this search for applications of computer-aided analysis of the formulaic style. While the new methodology that we propose does not directly evolve from any of the approaches described above, it is our hope that it will produce more in-depth analysis and more accurate descriptions of recurring lexical-rhythmic elements in Greek hexameter and verse in general.

2   Method

We developed a Python program called `Hexametron` that automatically scans Greek hexameter. This program is also able to process lines that present challenges because, for example, they contain the false diphthongs εω and εα, omit a consonant whose presence in a word must be assumed (e.g. ἔδϝεισε instead of ἔδεισε), or include a caesura in the third foot that must be assumed to produce an elongation (e.g. χείλει ἐφεσταότες · ἀπὸ γὰρ δειδίσσετο τάφρος, Il. XII, 52). Of the 15,682 total lines in The Iliad, `Hexametron` correctly scanned 15,328, that is, 97.7%.

Using `Hexametron`'s output, we developed a second program that associates each word with its position within the hexameter. We named this association a *topolexis* (τοπολέξις: from the Greek τόπος, "place" and λέξις, "expression, word"). Using this approach, the first line of *The Iliad* (Μῆ-νιν ἄ-|-ει-δε θε-|-ὰ Πη-|-λη-ϊ-ά-|-δεω Ἀ-χι-|-λῆ-ος) was transformed, for example, into 11Μῆνιν12 13ἄειδε22 23θεα31 32Πηληϊάδεω51 52Ἀχιλῆος62. Here, the word Ἀχιλῆος begins at the second syllable of the fifth foot (52) and ends at the second syllable of the sixth foot (62) while the word θεά begins at the third syllable of the second foot (23) and ends at the first syllable of the third foot (31). As can be seen, in these double-digit numbers that precede or follow the word, the first digit refers to the foot where the word begins or ends and the second to the syllable in that foot.

To explore the behavior of topolexes, we ran a series of tests on a textual corpus consisting of portions of *The Iliad* (the first 5,837 lines) and *The Odyssey* (the first 5,837 lines) and the entire text of Apollonius Rhodius' *The Argonautica* (5,837 lines). The size of the text sample was, of course, determined by the length of the shortest text (*Argonautica*). For each text, we established all of

The Iliad, 1–5837		The Odyssey, 1–5837		The Argonautica	
Topolexis	Rec.	Topolexis	Rec.	Topolexis	Rec.
12δ'12	356	12δ'12	349	21δ'21	221
21δ'21	247	11ὥς11	239	12δ'12	184
33καί33	203	21δ'21	229	32τε32	167
12δέ12	199	33καί33	215	11καί11	142
32καί32	193	11καί11	184	33καί33	136
42καί42	169	22δ'22	183	22δ'22	125
22δ'22	165	11ἀλλ'11	178	32δέ32	121
11καί11	160	32καί32	177	52δέ52	121
11ἀλλ'11	158	42καί42	162	12δέ12	113
11ὥς11	150	32τε32	145	22καί22	112

Table 1: The most common topolexes and their recurrence

the topolexes that it contained as well as the number of times that each one appeared.

3   Findings and Data Analysis

Table 1 presents the 10 most common topolexes along with the number of times they occur in each text. As the table makes clear, each topolexis contains a coordinating conjunction that occurs in various positions in the hexameter (the sole exception is ὥς, which is an adverb, in Homeric texts). On their own, these data shed some light on the functioning of hexametric lines and their syntactic tendencies.[5]

We were, however, primarily interested in the recurrence of content words and their distribution. For this reason, we excluded all function words from our lists by applying a stop-word list (this included conjunctions, articles, demonstrative adverbs, and pronouns). Having, thus, filtered our data, we obtained the results given in Table 2 (for the full data, see footnote 5).

Figure 1 is a line-plot which represents the 20 most common topolexes. These are sorted in descending order by frequency (x-axis) and number of recurrences (y-axis) and plotted on a logarithmic scale. As can be seen, *The Argonautica* differs strikingly from Homer's works: there are fewer recurrences of the most common topolexes in the former than in the latter.

Table 3 shows the number of topolexes that occur between 1 and 20 times in each sample (for the full data, see footnote 5). Here the first row gives the number of unique topolexes in each text while subsequent entries list the number of topolexes that recur, for example, 3, 10, 15, and 17 times. We can see that in *The Iliad*, for example, there are 14 topolexes that recur 16 times while there are 12 such topolexes in *The Odyssey* and 3 in *The Argonautica*.

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[5] The full data are available in CSV format at https://cutt.ly/ohzJfjY.

The Iliad, 1–5837		The Odyssey, 1–5837		The Argonautica	
Topolexis	Rec.	Topolexis	Rec.	Topolexis	Rec.
53Ἀχαιῶν62	104	53Ὀδυσσεύς62	72	42ἁλός43	30
53Ἀχαιοί62	62	53Ἀθήνη62	60	51Αἰήταο62	27
52Ἀγαμέμνων62	61	61θυμῷ62	44	12φάτο13	25
53Ἀχαιούς62	46	61εἶναι62	40	13ἔφη21	24
33Ἀχαιῶν42	44	12ἔφατ'13	38	11νῆα12	23
32προσέφη41	44	53θαλάσσης62	36	53Ἰήσων62	23
53μάχεσθαι62	39	32προσέφη41	34	53ἰδέσθαι62	22
53Ἀθήνη62	39	51δῖος52	33	53ἔειπεν62	22
33Διός41	35	33θεοί41	33	33Διός41	20
61ἵππους62	35	33θεά41	32	52προσέειπεν62	20

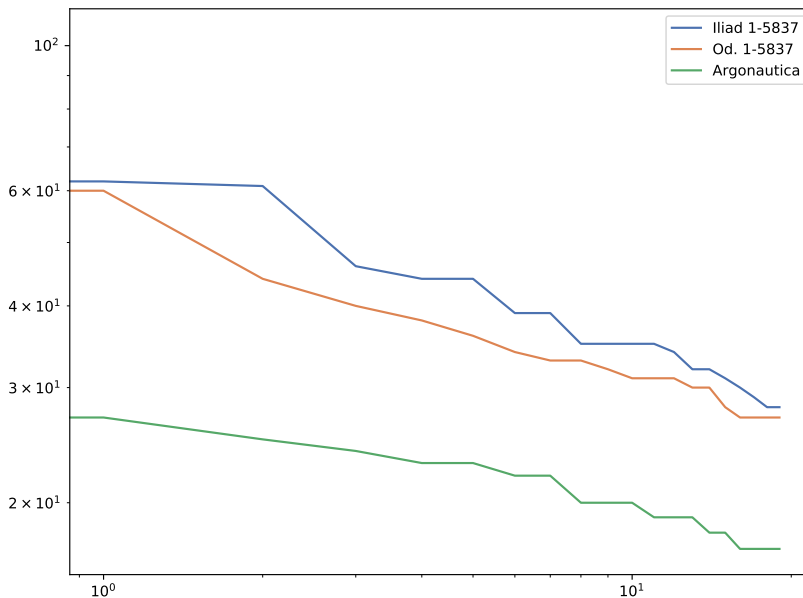Table 2: The most common topolexes and their recurrence (content words only)

Figure 1: The 20 most common topolexes (content words only) and their recurrence plotted on a logarithmic scale

The number of unique topolexes in *The Argonautica* also turns out to be 20% higher than the figure for *The Iliad* and 26% higher than the result for *The Odyssey*. Notably, the results for topolexes that recur 2 to 10 times are somewhat similar across all three texts. However a trend emerges when we consider topolexes that recur more than 10 times: there are fewer of these higher-frequency topolexes in *The Argonautica* than in the two Homeric texts. Figure 2 plots the data in Table 3 on a logarithmic scale. We can see a clear differ-

Frequency	*The Iliad*, 1–5837	*The Odyssey*, 1–5837	*The Argonautica*
1	9599	9120	11517
2	2004	2018	1968
3	750	790	708
4	361	374	296
5	212	221	164
6	132	146	120
7	82	86	75
8	61	55	54
9	39	47	35
10	31	23	21
11	29	22	15
12	26	18	6
13	14	23	6
14	9	17	6
15	12	7	10
16	14	12	3
17	7	8	4
18	5	10	2
19	5	6	3
20	4	6	3

Table 3: Total number of topolexes of each frequency (content words, from 1 to 20)

ence between *The Iliad* and *The Odyssey* on the one hand and *The Argonautica* on the other: high-frequency topolexes occur at a higher rate in the Homeric works.

Based on the same dataset, if we increase our range to the 50 most common topolexes and normalize the values, we obtain the results in Figure 3 (violin plot). This graph is probably most representative. It clearly shows that the distribution of topolexes of various frequencies is nearly identical in the two Homeric poems and very different in Apollonius' text. In addition, we see a thickening of *The Argonautica* graph that reflects its greater number of unique topolexes compared to the Homeric samples. In contrast, the thickening in the top part of the graphs for *The Iliad* and *The Odyssey* corresponds to their higher count of high-frequency topolexes.

Finally, we wished to investigate the correlation between the total number of topolexes and the number of recurring topolexes in our texts. To do this, we used the following formula:

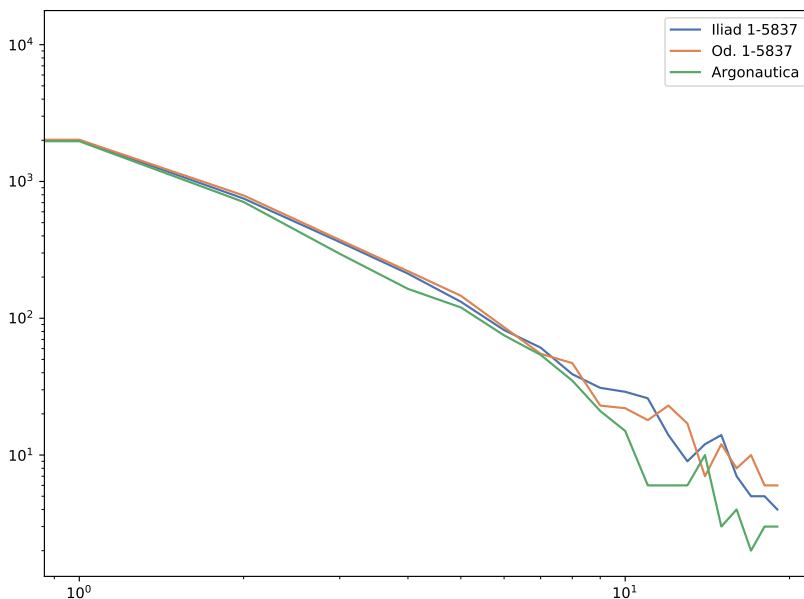$$FR = \frac{total\ number\ of\ topolexes}{number\ of\ distinct\ topolexes} \tag{1}$$

Figure 2: Total number of topolexes of each frequency (content words, from 1 to 20) plotted on a logarithmic scale
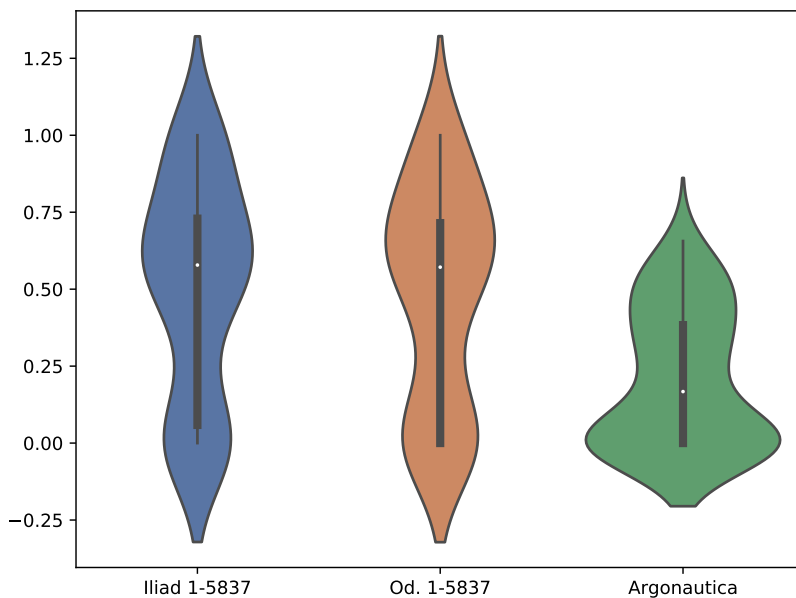

Figure 3: Total number of topolexes of each frequency (content words, from 1 to 50); normalized data
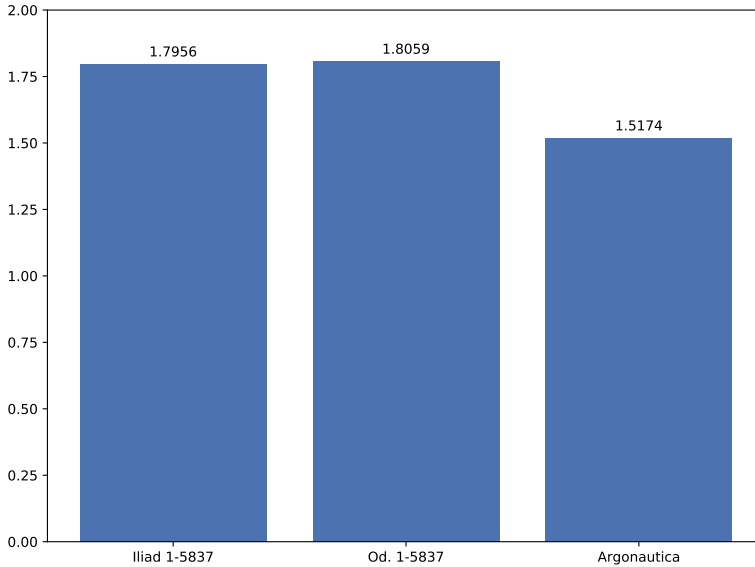
Figure 4: Formulaicity ratios

We called the resulting number the "formulaicity ratio".[6] Figure 4 shows our results for the three samples (*The Iliad*: 1.80; *The Odyssey*: 1.81; *The Argonautica*: 1.52).

 The formulaicity ratio was, thus, higher for *The Iliad* and *The Odyssey* than it was for *The Argonautica*. This suggests that the Homeric texts contained a lower number of unique topolexes, that is, they showed greater "formulaicity".

4   Analysis of an Additional Corpus Including Hesiod's Hexameter

We wished to apply the analysis above to a corpus that included an additional sample of Ancient Greek hexameter: Hesiod's *The Theogony*. There are only 1,023 lines in this text so its inclusion in the main corpus would have excessively reduced the size of the other sample texts. After selecting fragments of the same size from *The Iliad, The Odyssey,* and *The Argonautica*, we therefore compiled a new corpus. The line plot in Figure 5 depicts the 20 most common topolexes in each text, as sorted in descending order by frequency (x-axis) and number of recurrences (y-axis) and plotted on a logarithmic scale (cf. Figure 1). As the graph illustrates, although *The Theogony* is not identical to the Homeric works, it is closer to them than it is to Apollonius's text.

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6   As briefly noted in our introduction, the definition of a "formula" remains controversial. Based on our data and for strictly practical reasons, we therefore limited the term "formula" to topolexes that occurred more than once in the same rhythmic position in the hexameter. This was also the sense in which we used the term "formulaicity".
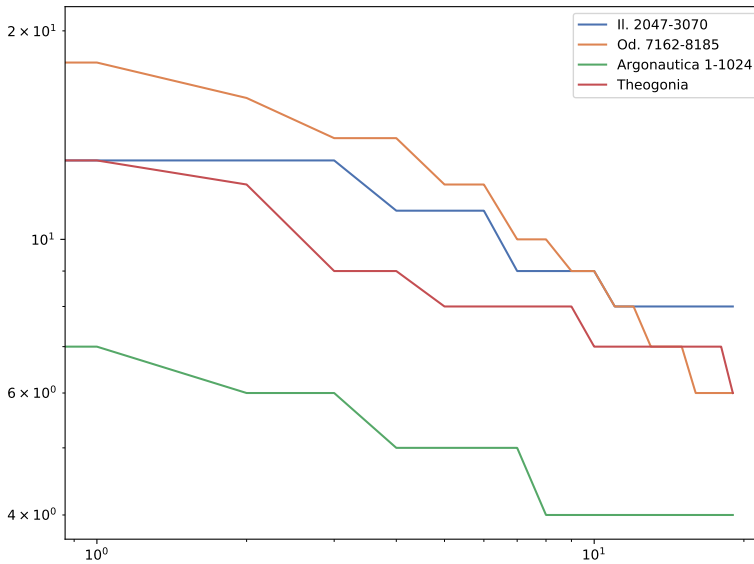
Figure 5: The 20 most common topolexes and their recurrence (content words only) plotted on a logarithmic scale

Figure 6 is analogous to the violin plot model in Figure 6 with the addition of *The Theogony*. Based on even this small sample, we may conclude that Hesiod demonstrates the same behavior regarding topolexes as Homer. This behavior is also characteristic of the formulaic style of poetry.

The formulaicity ratios for this corpus are as follows:

- *The Iliad*, 2047–3070: 1.30

- *The Odyssey*, 7162–8185: 1.32

- *The Argonautica*, 1–1024: 1.15

- *The Theogony*: 1.32

5   A Comparative Stylometric Experiment

One popular indicator in contemporary stylometry is the relative frequency of the most frequent words (MFW) (see Plecháč et al. 2018, including its bibliography). This indicator is obtained as follows: we count the number of times a given word occurs in a text and then divide this figure by the total word count. Once these values are obtained, we can choose a given number of most frequently used words. Based on these MFW, we can then perform a multivariate analysis.

To calculate the stylometric proximity between texts or sets of texts, the "distances" are measured between them. Just as we measure the distance between two points on a Cartesian plane, we calculate the "distance" between
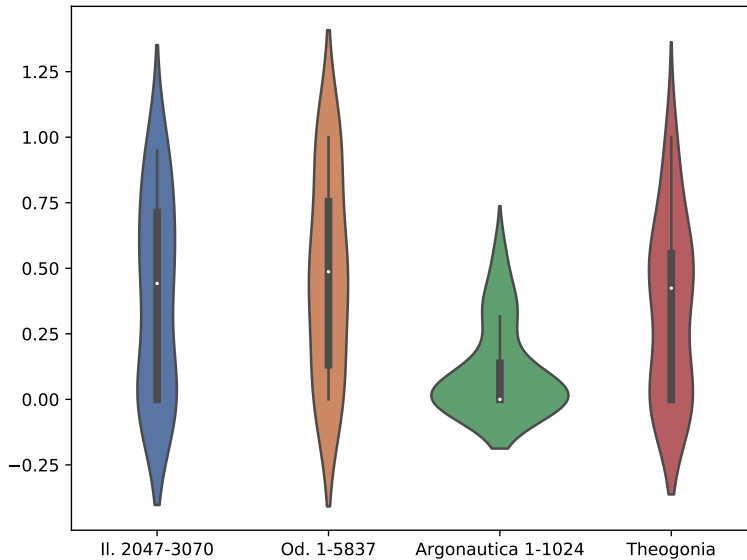
Figure 6: Total number of topolexes of each frequency (content words, from 1 to 50); normalized data

two texts (or sets of texts) based on the relative frequency of their most frequent words. Each text (or set of texts) is, thus, represented by a point in a multi-dimensional space where each coordinate is the value of the corresponding relative frequency, and the number of dimensions is the total number of most frequent words chosen for analysis. The distances thus obtained are then subjected to hierarchical clustering, and the outcome is often visualized as a tree diagram.

Generally speaking, the tree diagram that results from this cluster analysis is a graph with the following format: its y-axis shows the distances between the two texts while its x-axis shows the blocks established from the binary nodes based on those distances.

To assess the stylometric potential of topolexes, we compared the results of applying the clustering method to 1) the traditional indicator of MFW relative frequency and 2) the relative frequency of topolexes. Since we sought only to compare these two methods and were not interested in comparing the works with each other, we created a corpus consisting of Homer's *The Iliad* and Apollonius Rhodius' *The Argonautica*. We then ran the following test:

1. First of all, we divided *The Iliad* and *The Argonautica* into blocks of 750 lines each (this yielded slightly more than 5000 words per block, which is believed to be the minimum word count needed for this type of analysis to be efficient). We then calculated the distances between the texts and produced two tree diagrams: the first was based on the top 50 MFW while the second represented the 50 most common topolexes.

As can be seen in Figures 7 and 8, when applied to blocks of this length, both indicators yielded reliable results. The blocks from *The Iliad* and *The Argonautica* are, thus, respectively grouped together and form two separate clusters.

2. We repeated the experiment with blocks containing 350 lines each. As Figures 9 and 10 show,[7] both stylometric indicators again yielded good results.

3. We also achieved reasonably good results for both stylometric indicators when using smaller blocks of 100 lines each. To make this work, however, we had to extend the ranges to the 350 most common words and the 900 most common topolexes, as illustrated in Figures 11 and 12 (see footnote 7).

4. Finally, when using blocks smaller than 50 lines, we found that no matter how much we extended the frequency ranges (and even when we went as high as the 10,000 most common words/topolexes), we failed to obtain satisfactory results for either the MFW or the topolexis indicator (the best results can be seen in Figures 13 and 14; see footnote 7).

Our initial hypothesis was that topolexes might be a better stylometric indicator for verse texts. The results above did not, however, confirm our thesis: while topolexes allow us to correctly cluster fragments by author, they do not outperform the MFW in this respect.

6   Conclusion

We investigated the behavior of topolexes in a corpus of texts which included Homer's *The Iliad* and *The Odyssey* and Apollonius Rhodius' *The Argonautica.*
    Our findings showed that Apollonius' text has a higher number of unique topolexes while Homer's works contain more high-frequency topolexes. The "formulaicity ratio", i.e. the ratio of the number of different topolexes in a text to its total topolexis count, is higher for Homer than it is for Apollonius. Our indicator, thus, accurately reflected the greater formulaicity of Homer's texts.
    Our analysis of Hesiod's *The Theogony* by the same method demonstrated its similarity to Homer's poems in terms of topolexis behavior.
    Finally, we ran a test to compare the performances of the topolexis and the MFW as stylometric indicators for determining authorship. We found that while topolexes enable the correct clustering of fragments by author, they do not outperform the MFW in this regard.
    We have limited the current article to the presentation of the main quantitative results of our study. However a qualitative analysis of issues such as poetic syntax, style, and topolexis distribution by line has yet to be conducted.

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[7] Tree diagrams corresponding to Figures 9 to 14 can be found at: https://cutt.ly/ohzJfjY. That site also includes all of the texts scanned and tokenized by topolexis (in CSV format) as well as tables with full topolexis lists for each text sorted by frequency.

Figure 7: MFW

Figure 8: Topolexes

As a next step for future research, we envisage a study of typical topolexis sequences within the hemistich and the line as well as the application of our method to other verse forms. In the meantime, we hope that we have added another useful instrument to the toolkit for stylometric analysis.

Acknowledgments

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