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TIME SERIES MODELLING IN THE ANALYSIS OF HOMERIC VERSE

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ABSTRACT: Among other techniques of oral composition, the rhythmicity of hexameter seems to play a role in memorising and re-composing in performance long sections of Greek epic poetry. The article attempts to explain what feature of hexameter makes it rhythmical and thus suitable as an epic meter. Homeric verse was analysed using the ARIMA method. Roughly a hundred ten-verse samples from the *Iliad* were coded as binary sequences of two types. In one type of coding, verses were represented as sequences of long and short syllables, while in the other type, assuming the existence of *ictus* (metrical stress), as series of dynamically stressed and unstressed ones. The results, obtained using estimated linear models of stochastic processes, clearly suggest that the stress-based series are more rhythmical than the quantity-based series. This can be taken as an argument in favour of the reality of *ictus* in Greek hexameter.

INTRODUCTION

Homer's poems, and early epic poetry in general, cannot be described as typical written poetic output. They belong to archaic oral tradition of epic singing, which means that they were not composed as fixed texts but re-composed in performance. Nevertheless, they were not totally improvised: epic singers were assembling their poems using some techniques of oral composition, such as formulaic structure, fixed epithets of gods and heroes, traditional phraseology, theme patterns, etc.[1]

In spite of text variations and singers' freedom of choice in performance, there is something incredible in the fact that the ancient Greeks could re-compose from memory long sections of Homer's poems. Some claimed to have memorised the whole *Iliad* and *Odyssey*, which amounted to almost 30,000 lines. To achieve this impressive feat, excellent memorisation techniques were not enough. In terms of textual organisation, the epic poems must have displayed features that aided memorisation. These certainly included formulaic structure, the frequent occurrence of fixed epithets, etc., and probably *rhythmical patterning* as well.

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[1] Cf. e.g., Parry 1971; Lord 1960; 1991; Nagy 1979; 1996; Foley 1993.

Hexameter, the main epic metre, was quite flexible in rhythm shaping; among other ancient verse types it was probably the most dependent on the author's freedom of choice. Nevertheless, though each line of hexameter could be realised, theoretically, in thirty-two ways, the authors favoured some patterns[2]. The formulaic structure preferred fixed rhythmical schemes, and the authors were aware of it when choosing fixed epithets and other formulas[3]. The rhythm of hexameter is also shaped by another feature: rhythmically justified line endings[4]. When taking those facts into account, it is possible, and probable, that the rhythmicity of hexameter played an important role in the oral composition as one of the techniques supporting memorisation. In other words, it is probable that the epic singers were re-composing their poems on the basis of some repeating rhythmical patterns which can be discovered in analysis.

Like any binary phenomenon, rhythm can be described by means of quantitative methods. Existing research has largely confirmed the insufficiency of conventional statistics in modelling versification and/or prosody. Methods defined as conventional are based on the presumption that a text can be treated as a typical statistical population, or a set of elements in which the sequential order of units is not a relevant feature ("language in the mass")[5]. It may be asked, however, whether the kind of text segmentation that disregards the sequential order of units will prove effective in research on prosody and versification ("language in the line")[6]. In general, the rhythmical structure of a text depends on the linear order of marked and unmarked syllables (long/short, dynamically stressed/unstressed, high/low) that make up superordinate units, such as metrical feet or rhythmical groups. The regularity of a sequence may vary, and there can also be strong relationships between units that are not adjacent, but distant from each other at a fixed interval (e.g. the length of a single verse).

Statistics offers a number of sequential analysis methods that allow us to measure the linguistically relevant features of a text in the line[7]. They are e.g. Shannon's theory of information, the theory of Markov chains, spectral analysis and time series analysis. In the present study, we apply the time series analysis in the time domain. This methodology has been so far very efficient in the research of text rhythm and versification. The objects of analysis have usually in-

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[2] Foley 1993: 73.

[3] Parry 1971: 8–21.

[4] Foley 1993: 71.

[5] Herdan 1966: 423.

[6] Ibidem.

[7] Cf. Gottman 1981; 1990; Pawłowski 2005.

cluded such units as series of sentences[8], lexemes[9], syllables[10], letters[11], segments in Chinese[12], and intervals between the consecutive occurrences of lexemes and morphemes[13].

In a subsequent study, time series analysis was also used to examine the rhythmical organisation of Latin hexameter[14]. Based on a substantial corpus of Horace's, Ovid's and Virgil's texts, Latin samples coded as stress sequences were shown to be considerably more rhythmical than the same samples coded with regard to quantity. This observation permitted us to conclude that, in spite of its fundamental dependence on quantity, Latin hexameter also displayed metrical stress. A successful application of time series analysis in the study of Latin hexameter has encouraged our interest in epic memorisation with reference to Greek metre.

The authors are aware of the complexity of Greek verse types (both stichic and non-stichic) as well as versification patterns. In the present study, we focused only on Homeric hexameter, without taking into account the presumably older verse forms. Although the results of the analysis suggest some linguistic features of Greek metre in general, the conclusions do not apply to other verse forms than epic hexameter.

QUANTITY AND *ICTUS* IN GREEK VERSIFICATION

Rhythm in language is a binary phenomenon or – in other words – it consists in the opposition of marked and unmarked linguistic units. The basic factor of rhythm, or the relevant metrical feature is either word stress (in stress-based versification) or syllable length (in quantity-based versification)[15]. In classifying a versification system as stress- or quantity-based the question has to be answered as to which prosodic feature is most important in text creation and recitation.

In the case of ancient Greek the decisive feature is doubtless quantity, or the phonological opposition of long and short vowels, as in words [*lĕgo*] – 'to pick out' and [*lēgo*] – 'to stay, abate'. As syllable peaks in terms of loudness, vowels also lend their relevant characteristics to the syllables they constitute. A long vowel always generates a long syllable while a short one may constitute either

[8] Oppenheim 1988; Pawłowski 1998: 124–153; Roberts 1996; Schils, De Haan 1993.

[9] Corduas 1995; Pawłowski 1998: 96–111.

[10] Azar, Kedem 1979; Bratley, Ross 1981; Pawłowski 1999; 2000; 2001; 2003; 2004.

[11] Petruszewycz 1981.

[12] Dreher, Young, Norton, Ma 1969.

[13] Pawłowski 1998: 113–124.

[14] Pawłowski, Eder 2001.

[15] Kuryłowicz 1975: 241 f.

a short or a long syllable (when the vowel is a short one, syllable length depends on whether it is open or closed). An ordered sequence of long and short syllables generates verse rhythm. Greek metre is therefore an example of typically quantitative versification.

Syllable length is then a basic factor of rhythm, but there may be others to consider as well. For several scholars, an ordered sequence of long and short syllables is sufficient to make a text sound rhythmical in performance. However, this condition does not seem sufficient to the relatively few proponents of a special dynamic stress called *ictus*, which may partially overlap with word stress depending on the genre of the poem. A sample line from Homer's *Iliad* I 2 (οὐλομένην, ἣ μυρί' Ἀχαιοῖς ἄλγε' ἔθηκε) can be marked for quantity as follows:

[*oūlŏmĕnēn hē mūrĭ Ăchaīoīs ālgĕ ĕthēkĕ*]

Proponents of quantity view the rhythmical quality of the verse above as generated exclusively by the sequential order of syllables: ×̄×̆×̆×̄×̄×̄×̆×̆×̄×̄×̄×̆×̆×̄×̆. Adherents of the *ictus* hypothesis argue on the other hand that rhythm will gain prominence when some syllables are foregrounded through metrical stress assignment:

[*oū́lŏmĕnḗn hē mū́rĭ Ăchaī́oīs ā́lgĕ ĕthḗkĕ*]

Placed in strictly defined positions within the series, *ictus* makes the line more rhythmical, so that it eventually takes the form: ×̄́×̆×̆×̄́×̄×̄́×̆×̆×̄́×̄×̄́×̆×̆×̄́×̆. It has to be emphasised that *ictus* is a verse transposition of word stress, which does not imply that both should always coincide:

[*oū́lŏmĕnḗn hē mū́rĭ Ăchaī́oīs ā́lgĕ ĕthḗkĕ*]

In this series, only one stressed syllable additionally receives *ictus*: in word [*ā́lgĕ*].

The majority view among scholars is that rhythm was based on quantity both in Latin and Greek metre. The historical connections between the two systems of versification cannot of course be denied. Latin versification was *de facto* an implementation of Greek principles, and it is common knowledge that Greek metrical forms had effectively ousted the indigenous Saturnian verse by 240 BC. Given these links, it will be natural to appeal in our discussion to indirect judgements about Greek metre in passages that were explicitly concerned with its Latin incarnation.

The main argument against *ictus* is that ancient writers are consistently silent about it[16]. The concepts of *arsis* and *thesis*, now applied to strong and weak syllables respectively, were used in antiquity with reference to dancing only, and cannot be cited as evidence in the present context. Similarly, the task of sorting out the *ictus* controversy is not made any easier by consulting ancient grammarians, metre theorists, and musicologists, whose observations are generally of limited value due to terminological fuzziness[17]. Apart from the argument from silence, *ictus* has also been attacked on other grounds. F. NIETZSCHE was the first writer aesthetically to challenge the *ictus* hypothesis from a subjectivist point of view[18], taking issue with the standard theory as developed in G. HERRMANN's groundbreaking study[19].

After NIETZSCHE's spirited attack further scholarly criticisms followed. Research on rhythm in general has suggested that there can be purely quantitative rhythm, though it is less prominent than dynamic rhythm[20]. This abstract thesis is corroborated by the rhythmical qualities found in musical instruments such as the organ or bagpipe, in which rhythm cannot begin to arise out of changes in volume (counterpart to expiratory *ictus*)[21].

Opponents of *ictus* have often realised that quantitative rhythm can occasionally be strengthened by pitch, as evident from the Delphic hymns of the second century BC[22]. Some scholars take it to have been a deliberate poetic device[23], while others regard it as an insignificant accidental coincidence[24]. Without trying to resolve the debate, it is necessary to emphasise that Greek tonal accent had nothing to do with the dynamic *ictus*.

Whether *ictus* really existed is also questioned by phoneticians on the one hand and students of Greek drama in performance on the other. Phonetics experts have wondered why there is no evidence of any effects of the allegedly salient *ictus* on poetic language, such as reduction of syllables without *ictus*. Historians of ancient drama have maintained that a Greek spectator would have been confused at hearing two phonetic realisations of the same word, not too distant from each other in the text and pronounced differently as a result of *ictus* placement. To take an example from Euripides's *Hecuba*, for instance, the spectator would have

[16] SICKING 1993: 11.

[17] ALLEN 1973: 275 f.

[18] NIETZSCHE 1912: 336.

[19] HERRMANN 1816.

[20] MEILLET 1923: 10.

[21] SONNENSCHEIN 1925: 24 f. and 203.

[22] DEVINE, STEPHENS 1994: 168 f. and 173; cf. WACKERNAGEL 1896: 204 f.; COMOTTI 1989: 91–108.

[23] SNELL 1982: 6, n. 11; ZAYTSEV 1994: 21.

[24] SICKING 1993: 64.

heard, within a space of only two lines, the same form ἐνεγκοῦσαι pronounced as [enenkoúsai] and [enénkousaí][25]. In sum, the majority opinion is that *ictus* was invented by modern scholars[26] and can be traced to the classroom tradition. In this school of performance, Greek and Latin poems are still recited in such a way that heavy dynamic stress is put emphatically on syllables with *ictus*[27].

However, there are also convincing claims of a more general scope, frequently made in metre theory and structuralist linguistics, that allow us to argue in favour of a non-quantitative stress. Especially significant in this respect are the findings of J. Kuryłowicz. Drawing on a remarkable variety of material, he has demonstrated that the presence of quantity as a phonemic feature in a given language system is not a sufficient condition for quantitative versification to arise in that language[28]. Moreover, the intricate ordering of long and short syllables does not itself make for a quantitative metre, as evident from the example of Russian versification[29]. According to Kuryłowicz, there are two necessary conditions for a quantitative metre to emerge: the phonemic status of quantity and the possibility of shifting and blurring word boundaries. It is precisely the phonetics of the word boundary, or metrical *sandhi*, that makes the opening of the *Iliad* (Μῆνιν ἄειδε θεὰ Πηληϊάδεω Ἀχιλῆος):

[*Menin aeide thea Peleiadeo Achilleos*]

sound as follows in performance:

[*Menina eidethe ape leia deoachi leos*]

When recited, the line above becomes a unit of an entirely different order, composed not of semantic words but asemantic syllables. Consequently, word pitch does not count as a rhythmic factor: as word boundaries are no longer relevant, word pitch cannot perform a demarcative function. The metric units (feet) formed by *sandhi* are still in need of foregrounding. The culminative function of word pitch in verse must be taken over by a different characteristic of syllabic groups, namely metrical stress, or *ictus*[30].

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[25] Zaytsev 1994: 32.

[26] Korzeniowski 1998: 34–39; Leonhardt 1989: 14 (n. 12); Stroh 1989: 62–89; 1990: 87–113; West 1982: 196.

[27] Cf. recordings on the CD attached to: Glau 1998.

[28] Kuryłowicz 1975: passim.

[29] Zaytsev 1994: 6.

[30] Kuryłowicz 1950: 37; 1972: 3 f.

Versification is never disengaged from ordinary language. Several features of the Greek language system have their exact counterparts in Greek versification[31], some of which are instances of prosodic equivalence. The post-accentual tail of a Greek verbal form may consist of a long syllable e.g. [*el*^{i}*pū*], or two short syllables [*l*^{ei}*pŏmĕn*], or else a long-short syllabic complex [*l*^{ei}*pōmĕn*]. In terms of the stress placement in Greek verbal inflection, it is then possible for equivalence $\bar{\times} = \breve{\times}\breve{\times}$ to obtain in a post-stress position. A syllabic correspondence of the same sort is possible in a post-ictus position in Greek metre as well[32]. This sort of equivalence between accentuated vowels obtains not only in metre but also beyond verse in Greek in general. In this broader context, it is not limited to verbal accentuation, but concerns the familiar phenomenon of two short syllables blending into a single long one, e.g. [*perikall*$^{\breve{e}}$*ŏs*] = [*perikal*$^{o\bar{u}}$*s*]. In versification, this corresponds to response in ictus-positions $\acute{-} = \acute{\smile}$[33].

A number of specific arguments and hypotheses have also been advanced in favour of *ictus*. It was essential, some have claimed, for when a song composed of specific metrical measures was performed during a procession, metrical stress must have coincided with instances of downbeat, or the performer's putting his foot to the ground[34]. Given the alleged absence of *ictus*, there would be no room for rhythm in a verse line which consisted exclusively of long syllables. A sample line from Homer's *Iliad* XXIII 221: ψυχὴν κικλήσκων Πατροκλῆος δειλοῖο can be represented as follows: [- - - - - - - - - - - -]. It should be clear that, as it is, there can be no rhythmical effect in this verse. It is only by placing *ictus* on the first syllables of the particular feet that the line becomes properly rhythmical: [$\acute{-}$ - $\acute{-}$ - $\acute{-}$ - $\acute{-}$ - $\acute{-}$ - $\acute{-}$ -].

Another argument in favour of *ictus*, though an indirect one, has been supplied by R. SCHMIEL[35] who developed the seminal concept of correspondence of *ictus* and word stress in Vergil's *Aeneid* proposed by W.F. JACKSON KNIGHT[36]. Having examined a total of twelve books from the *Iliad*, SCHMIEL found a significant nearly thirty-percent "coincidence between the six regularly-recurring heavy syllables and acute and circumflex accents", which occurred much more frequently in dialogues than in narrative sections[37]. This deliberate patterning would not be noticeable if *ictus* were merely a scholarly fiction. SCHMIEL's findings allowed him to assert boldly that "we must give up our neat, water-tight

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31 Cf. DEVINE, STEPHENS 1994: 102–117.

32 KURYŁOWICZ 1961: 88 f.

33 Ibidem, p. 88; cf. KURYŁOWICZ 1976: 65 f.

34 ZAYTSEV 1994: 34 f.

35 SCHMIEL 1981.

36 JACKSON KNIGHT 1939: 12–14.

37 SCHMIEL 1981: 5.

categories of stress, quantity, dynamic and pitch-accent, and we may conclude that in both Greek and Latin poetry, as in the poetry of other languages, the linguistic phenomena stress, quantity, and accent are correlated"[38].

Neither the theoretical observations about the nature of rhythm as such, nor the specific comments on Greek epic poetry – contrary to the contemporary view of *ictus* as a modern invention (*ictus fictus*) – have helped us reach a convincing solution to the problem.

HYPOTHESIS

In view of all the facts discussed thus far, it was hypothesised that the rhythm of the orally transmitted Homeric epics may have been generated by the non-random ordering of long and short syllables and/or dynamic metrical stress. The authors are aware of different nature of both prosodic features. However, as they may coexist and overlap in a metrically organised text, they can undergo contrastive analysis. We also assumed that it was possible to code any poetic text as two different time series: one generated with respect to quantity, the other with respect to *ictus*. If the stress-based series turns out to be more rhythmical than the quantity-based one, and the sequence of long and short syllables proves only weakly rhythmical, we will then have an important empirical argument in favour of the existence of dynamic metric stress in Greek epic poetry as recited in performance.

DATA AND QUANTIFICATION

To verify the hypothesis, we chose one of the Homeric poems, the *Iliad*. It represents the classical measure of Greek epic poetry as well as the most popular and best preserved form of Greek versification in general: dactylic hexameter. It may be the case that some inherent features of hexameter naturally facilitate memorisation, thus making it an extremely popular choice as an epic meter.

In its classical form, hexameter is a sequence of six dactylic feet, the last of which is catalectic (incomplete). The last syllable in each verse can be either long or short [–́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏓]. Writers usually replace some (or all) dactyls [–́ ⏑ ⏑] with spondees [–́ –]. Thus, theoretically there are thirty-two possible realisations of the hexametric line. In practice, however, some of them are very rare (e.g. a spondee as the fifth foot). Consequently, the rhythmical structure of epic verse is to some extent irregular: neither fully deterministic, nor completely devoid of any formal determinants of rhythm.

[38] Ibidem, p. 25. Similar statements with reference to Greek dance in performance – cf. David 2006: 66 f.

We coded 96 samples from the *Iliad* (four randomly chosen ten-verse excerpts per book)[39]. The average length of a sample was 167 syllables. The quantification procedure was as follows. For each sample we generated a time series based on quantity, assigning [1] to long syllables and [0] to short ones, e.g. a dactyl was coded as [1,0,0] and a spondee [1,1]. A parallel time series was generated for each sample based on metrical stress, where syllables with *ictus* were represented by [1] and those without ictus by [0]. Now a dactyl was still [1,0,0], but a spondee changed to [1,0]. Irrespective of its phonetic quality, the last syllable in a line was regarded and coded appropriately as long and unstressed[40].

A sample verse from the *Iliad* mentioned in the previous sections would be coded as follows:

[*oū́lŏmĕnḗn hē mū́rĭ Ăchaī́ŏīs ā́lgĕ ĕthḗkĕ*]
{100111001110011} for quantity and
{100101001010010} for metrical stress.

THE METHOD OF MODELLING

The method of modelling applied in this study, widely used within the field of the social sciences, is rather sophisticated and far from being intuitive. However, it provides reliable and credible results. Readers who are less acquainted with mathematics can skip this part and just assume that the coefficient V_e is a quantitative measure of text rhythmicity, while graphs with ACF and PACF functions display the depth and strength of sequential relations in verse.

To model empirical data, the ARIMA method was used as elaborated by G. Box and G. Jenkins[41]. The method has already been discussed in the literature with a view to possible applications in sociology and psychology[42]. The linguistic

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[39] A list of samples analysed: Hom *Il*. I 59–68, 164–173, 310–319, 407–416; II 41–50, 182–191, 592–601, 832–841; III 149–158, 228–237, 315–324, 404–413; IV 159–168, 278–287, 433–442, 465–474; V 150–159, 506–515, 663–672, 875–884; VI 81–90, 185–194, 302–311, 520–529; VII 13–22, 70–79, 254–263, 412–421; VIII 141–150, 198–207, 284–293, 448–457; IX 61–70, 182–191, 405–414, 492–501; X 113–122, 206–215, 429–438, 519–528; XI 87–96, 241–250, 398–407, 677–686; XII 117–126, 171–180, 227–236, 351–360; XIII 32–41, 195–204, 405–414, 722–731; XIV 187–196, 421–430, 459–468, 507–516; XV 263–272, 441–450, 656–665, 708–717; XVI 363–372, 527–536, 761–772, 841–850; XVII 53–62, 134–143, 492–501, 698–707; XVIII 190–199, 333–342, 409–418, 601–610; XIX 7–16, 338–347, 393–402, 411–420; XX 80–89, 157–166, 391–400, 454–463; XXI 142–151, 320–329, 386–395, 533–542; XXII 14–23, 80–89, 196–205, 273–282; XXIII 369–378, 442–451, 611–620, 789–798; XXIV 41–50, 345–354, 509–518, 574–583.

[40] Cf. West 1982: 4 f.

[41] Box, Jenkins 1976.

[42] Brockwell, Davies 1991; 1996; Chaghaghi 1985; Coutrot, Droesbeke 1984: 67–76; Glass, Wilson, Gottman 1975; Gottman 1981; McCleary, Hay 1980; Montgomery, Johnson 1976: 188–240; Nurius 1983; Pawłowski 1998; Stier 1989; Whiteley 1980.

implementations of the ARIMA method have been discussed by A. Pawłowski[43]. A brief introduction to the formal basics of the method will be given here insofar as it is necessary to follow the inference presented below.

A time series $\{x_1, x_2, \ldots, x_n\}$ is defined as a series of realisations of a random variable. The independent variable t , which traditionally stands for *real time*, is replaced in textual research by *syntagmatic time*, which corresponds to the sequential order of linguistic units[44]. The notion of an instant on the axis of real time thus finds its counterpart in the notion of a position in the linear arrangement of text. The interval between two realisations of a series at t_i and t_j is referred to as the *lag* and marked as $k = t_j - t_i$.

An important feature of time series generated from texts is their *stationarity*. A stationary series is stable in showing no tendency and having fixed positional parameters (e.g. statistical moments), regardless of which sections of the series have been taken into account[45]. Since linguistic units such as word length are quantitatively stable, time series obtained by means of text quantification may *a priori* be regarded as *stationary*.

The basic parameters of stationary time series include:

– the *arithmetic mean* (μ_x), which is estimated by means of:

$$m_x = \frac{1}{N}\sum_{t=1}^{N} x_t \tag{1}$$

where:

N – the length of the series;

x_t – the value of the series at instant or position t;

– the *variance* (σ_x^2) of time series, which, granted that notation remains consistent throughout, is estimated by means of:

$$s_x^2 = \frac{1}{N}\sum_{t=1}^{N} \left(x_t - m_x\right)^2 \tag{2}$$

– the *autocovariance* of time series at lag k (γ_k), which is estimated as follows:

$$c_k = \frac{1}{N-k}\sum_{t=1}^{N-k} \left(x_t - m_x\right)\left(x_{t+k} - m_x\right) \tag{3}$$

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43 Pawłowski 2001; 2005.

44 Pawłowski 1998: 4.

45 Priestley 1981: 112.

– the *autocorrelation* of time series at lag k (ρ_k), which is estimated by means of the function:

$$r_k = \frac{c_k}{c_0} = \frac{c_k}{s_x^2} \tag{4}$$

The basic time series models are presented below, each of them being a special instance of the *general linear* model. These models are called linear, because each value in the series (x_t) is a linear combination either of series values or of realisations of a random process at the preceding positions. A special type of time series is a purely random process.

A *random series* $\{e_1, e_2, e_3 ...\}$ is defined as the series of statistically independent realisations of a random variable. By way of an analogy with the light spectrum, the series of e_i-values with normal distribution $N(0,1)$ is referred to as *white noise*.

An *autoregressive series* of the p-th order, marked as AR(p), is defined as the series of x_t-values that are describable in terms of the model given below:

$$x_t = a_1 x_{t-1} + a_2 x_{t-2} + ... + a_p x_{t-p} + e_t \tag{5}$$

where:
a_i – coefficients of the model;
e_i – random values with normal distribution $N(0,1)$.

In linguistic terms, the order of a series corresponds to contextual depth or *text memory*. For any given syllable, the order of the series specifies how many preceding syllables have to be considered in predicting its phonetic (phonological) quality.

A *moving-average series* of the q-th order, marked as MA(q), is defined as the series of x_t-values that are describable in terms of the model given below:

$$x_t = e_t - b_1 e_{t-1} - b_2 e_{t-2} - ... - b_q e_{t-q} \tag{6}$$

where:
b_i – coefficients of the model;
e_i – random values with normal distribution $N(0,1)$.

The MA(q) model is harder to interpret linguistically than the AR(p) one. The preceding realisations of the series are not directly salient in the model, however, and more interestingly, equation 6 is a linear filter that transforms random e_i-values into an ordered and partially deterministic series $\{x_1, x_2, ..., x_n\}$. To be sure, there is some link between the series values and the preceding context, as the same combination of model coefficients b_i recurs for every x_t. Mathematically, realisations of the moving-average series are related to the history of the series because the AR and MA models are *invertible*. By virtue of invertibility, for every AR(p) process there is a corresponding MA(∞) process, and for every MA(q) process there is a corresponding AR(∞) process.

A *seasonal series* is defined as the series in which realisations show periodic regularity at fixed intervals s. Seasonal models are used in econometrics, where several market phenomena, such as prices, reveal regularity within monthly or annual cycles. Such models have proved to be an effective instrument in analysing textual data. They permit us empirically to examine versification, which consists in the repetition of chunks of text that are rhythmically and/or metrically equivalent.

A series is called seasonal of the type SARMA$(P,Q)_s$ if it is describable in terms of the model given below:

$$x_t = a_s x_{t-s} + a_{2s} x_{t-2s} + \ldots + a_{Ps} x_{t-Ps} - b_s e_{t-s} - b_{2s} e_{t-2s} - \ldots - b_{Qs} e_{t-Qs} + e_t \qquad (7)$$

where:
a_i – coefficients of AR;
b_i – coefficients of MA;
s – seasonal lag;
e_i – random values with normal distribution $N(0,1)$.

The notation might be simplified by means of operators. Thus, a back-shift operator of the s-th order is defined as follows:

$$B_s x_t = x_{t-s} \qquad (8)$$

In this notation, the general model of the seasonal stationary process SARMA$(P,Q)_s$ can be represented as follows:

$$x_t\left(1 - a_s B^s - a_{2s} B^{2s} - \ldots - a_{Ps} B^{Ps}\right) = e_t\left(1 - b_s B^s - b_{2s} B^{2s} - \ldots - b_{Qs} B^{Qs}\right) \qquad (9)$$

Up until now, quantitative research on versification has usually discovered combinations of simple and seasonal processes, the seasonal interval s being equal to the length of a verse or a sequence of verses[46]. In general, models of such processes are represented as SARMA$(p,q)(P,Q)_s$, where p and q stand for the respective orders of the normal components of autoregression and the moving

[46] Pawłowski 2001.

average, while P and Q signify the respective orders of the seasonal components. According to this convention, a typical model containing a seasonal component, such as SARMA(1,0)(0,1)$_s$, would be represented as:

$$(1 - a_1 B)(1 - a_s B^s) x_t = e_t \tag{10}$$

The most effective model is selected on the basis of the shape of the functions of autocorrelation (ACF) and partial autocorrelation (PACF). In statistics, PACF is used for the study of systems with multiple random variables when the object of inquiry is the direct correlation between two selected variables independently of interference from other variables. An advantageous characteristic of PACF is that it truncates at lag $p+1$ for an AR(p) series, and dies out as an exponential function or dying-out sinusoid for an MA(q) series. Given the directly opposite behaviour of ACF, the method for identifying a series can be described by means of a simple diagram[47]:

	ACF	PACF
AR(p)	dies out	truncates at lag p + 1
MA(q)	truncates at lag q + 1	dies out
ARMA(p,q)	dies out	dies out

Table 1. Identification of simple linear models

In the last stage of the research procedure, the goal is to estimate the goodness of fit of the model. The decisive variable here is the percentage of the original variance explained by the model. In order to calculate it, a residual series is generated that consists of the respective differences between the values observed and those predicted by the model. The variance of the residual series is then compared with that of the series under analysis. It is to be expected that an effective model will yield a residual series with very little variance. If the original variance is symbolised as s^2_{obs} and the variance of the residual series as s^2_{res}, the goodness of fit of the model (V_e) can be expressed as:

$$V_e = 100\% \left(1 - \frac{s^2_{res}}{s^2_{obs}} \right) \tag{11}$$

It is assumed that the better the goodness of fit, the higher the value of V_e. V_e also provides insight into an important quality of a text: as rhythmic series

47 Cryer 1986: 106.

are easier to model than non-rhythmic ones, the higher the value of V_e, the more likely a text is to be rhythmical. By virtue of the same fact, the higher the percentage of the original variance explained by the model, the more regular or rhythmical the series under analysis. Consequently, V_e is a linguistically relevant *comprehensive measure of the sequential orderedness of a text*. A separate question, and one which, in our view, cannot be answered by scholarship, is whether and, possibly, how to interpret this index of orderedness in aesthetic categories.

CASE STUDY

As an example of detailed analysis we chose one of 96 coded samples from the *Iliad* (III 258–267). The section concerns a future duel in which the fate of Troy is to be decided. The sample is composed almost exclusively of dialogue parts, and contains ten verses and 168 syllables. The Greek text is presented below alongside the sequences coded with regard to quantity and stress.

Ἄργος ἐς ἱππόβοτον καὶ Ἀχαιΐδα καλλιγύναικα.	–́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏓
Ὣς φάτο, ῥίγησεν δ’ ὁ γέρων, ἐκέλευσε δ’ ἑταίρους	–́ ⏑ ⏑ –́ – –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏓
ἵππους ζευνύμεναι· τοὶ δ’ ὀτραλέως ἐπίθοντο.	–́ – –́ ⏑ ⏑ –́ – –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏓
ἂν δ’ ἄρ’ ἔβη Πρίαμος, κατὰ δ’ ἡνία τεῖνεν ὀπίσσω·	–́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏓
πὰρ δέ οἱ Ἀντήνωρ περικαλλέα βήσετο δίφρον·	–́ ⏑ ⏑ –́ – –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏓
τὼ δὲ διὰ Σκαιῶν πεδίονδ’ ἔχον ὠκέας ἵππους.	–́ ⏑ ⏑ –́ – –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏓
Ἀλλ’ ὅτε δή ῥ’ ἵκοντο μετὰ Τρῶας καὶ Ἀχαιούς,	–́ ⏑ ⏑ –́ – –́ ⏑ ⏑ –́ – –́ ⏑ ⏑ –́ ⏓
ἐξ ἵππων ἀποβάντες ἐπὶ χθόνα πουλυβότειραν	–́ – –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏓
ἐς μέσσον Τρώων καὶ Ἀχαιῶν ἐστιχόωντο.	–́ – –́ – –́ ⏑ ⏑ –́ – –́ ⏑ ⏑ –́ ⏓
ὄρνυτο δ’ αὐτίκ’ ἔπειτα ἄναξ ἀνδρῶν Ἀγαμέμνων,	–́ ⏑ ⏑ –́ ⏑ ⏑ –́ ⏑ ⏑ –́ – –́ ⏑ ⏑ –́ ⏓

quantity:
{1001001001001001110011100100100111110011100100111001001001001
110011100100100111001110010010011100111001110011111001001001001111
1110011100111001001001110011}
metrical stress:
{100100100100100101001010010010010101001010010010100100100100100
1010010100100100101001010010010010100101001010010101001001001001
0101010010100101001001001010010}

The analysis of data starts with presenting the functions of autocorrelation (Fig. 1) and partial autocorrelation (Fig. 2) for the quantity-based series.

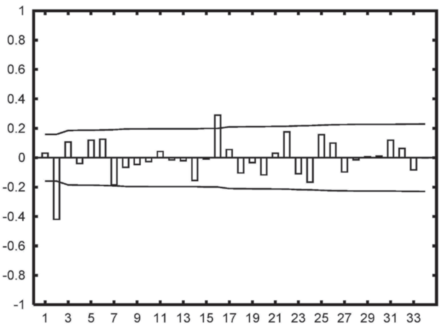

Fig. 1. ACF for the quantity series

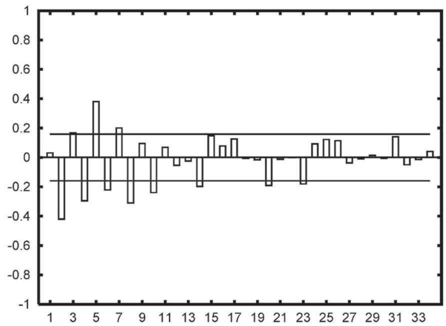

Fig. 2. PACF for the quantity series

On Fig. 1 and 2, as well as on the subsequent ones, ACF and PACF values are represented by vertical bars, while the confidence interval (so called Bartlett band) is marked with horizontal lines. The bars which exceed the confidence interval are significant: they suggest the presence of a deterministic component in data. The higher they are (in absolute value), the more predictable is the time series under analysis.

The shape of both graphs indicates the presence of a deterministic component, but fails unambiguously to suggest any particular type of model. As PACF consists of dying-out sinusoids, and ACF contains significant bars at lags 2 and 16, this is most likely to be some kind of a moving average model, possibly with a seasonal component. The first step in identifying the type of model is to estimate the MA(2) model:

$$x_t = \left(1 + 0.34B^1 - 0.63B^2\right)e_t \tag{12}$$

where:

x_t – series value at moment or position t;

e_t – random values with normal distribution $N(0,1)$;

B – back-shift operator.

As can be seen from Fig. 3, the residual series created by filtering out the deterministic component from the original data is not a random one, for there are significant correlations at lags 3 and 16. Because MA(2) proved to be unsatisfactory for our purposes, MA(4) was also estimated:

$$x_t = \left(1 + 0.65B^1 - 0.83B^2 - 0.11B^3 + 0.44B^4\right)e_t \tag{13}$$

The ACF of the residual series contains a significant bar only at lag 16. It follows from this that the seasonal model SARMA$(p,q)(P,Q)_s$ can be applied at $s = 16$. Fig. 4 shows the ACF of the residual series, which was obtained by filtering out the data generated by SARMA$(0,4)(1,0)_{16}$:

$$\left(1 - 0.32B^{16}\right)x_t = \left(1 + 0.6B^1 - 0.83B^2 + 0.44B^4\right)e_t \tag{14}$$

This series contains no significant values and model 14 can be considered satisfactory.

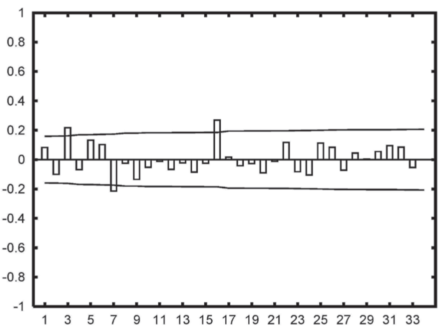

Fig. 3. ACF of the residual series for quantity, MA(2) model

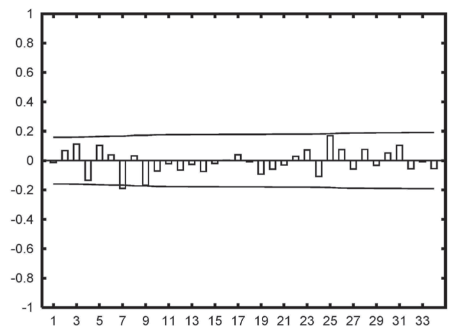

Fig. 4. ACF of the residual series for quantity, SARMA model

Table 2 shows the values of V_e that were calculated for the estimated models (for the original series $s^2 = 0.251$). The quality of the model can be observed to increase in proportion to the number of parameters. It is worth noting, however, that the seasonal component is only responsible for four percent of the total variance of the series. Interestingly, the bar at lag 16, though relatively low here, appeared regularly in most of the samples, both for the quantity- and stress-based series. This will be taken up again when we come to discuss the results.

	MA(2)	MA(4)	SARMA$(0,4)(1,0)_{16}$
s_2	0.154	0.128	0.117
V_e	39%	49%	**53%**

Table 2. The goodness of fit of the models estimated for quantity series

Exactly the same procedure was followed in estimating the model for the stress-based sequence. This time, however, the author of the *Iliad* proved much more obliging to us, since the shapes of the ACF graph (Fig. 5) and the PACF graph (Fig. 6) clearly suggest a process of the AR(2) type.

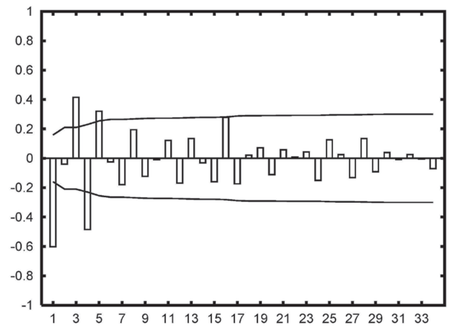

Fig. 5. ACF for the stress series

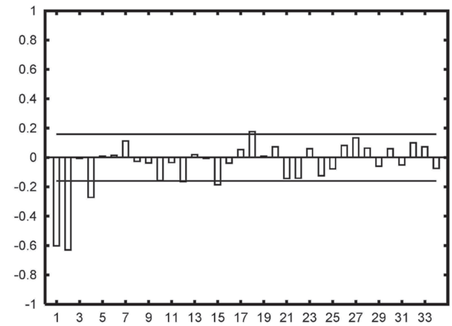

Fig. 6. PACF for the stress series

As a consequence, the first model to be estimated was the AR(2) as defined below:

$$\left(1 + 0.99B^{1} + 0.63B^{2}\right)x_{t} = e_{t} \tag{15}$$

The autocorrelation of the residual series obtained by filtering out the series was found to contain two significant values at lags 5 and 16 (Fig. 7). As the value at lag 5 turned out to be a random one (it failed to pop up regularly in the other samples), an additional SARMA(2,0)(1,0)$_{16}$ model was estimated:

$$\left(1 + 0.99B^{1} + 0.63B^{2}\right)\left(1 - 0.32B^{16}\right)x_{t} = e_{t} \tag{16}$$

This model proved more effective in filtering out a significant value of ACF at seasonal interval s = 16. The ACF of the residual series, which was obtained by filtering out the process generated by model 16, displays no significant values apart from the random value at lag 5 (Fig. 8).

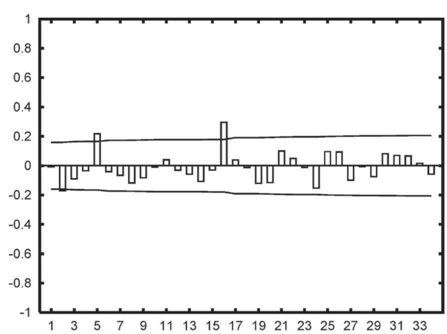

Fig. 7. ACF of the residual series for metrical stress, AR(2) model

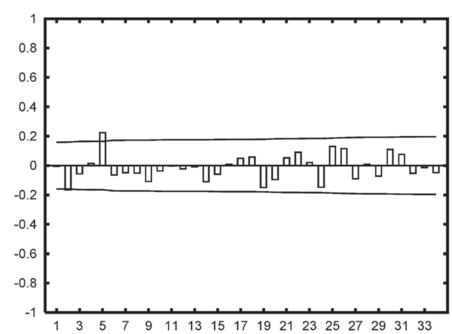

Fig. 8. ACF of the residual series for metrical stress, SARMA model

The values of V_e calculated for both models turned out to be very high: 62% for AR(2) and 65% for SARMA(2,0)(0,1)$_{16}$. The seasonal lag of sixteen syllables succeeds in explaining merely about 3% of the total variance of the series under analysis. As was the case for the quantity-based series, this value recurred regularly in most of the samples and that was the reason why it was taken into account. The values obtained for the sample under analysis are shown in Table 3 (for the observed series $s^2 = 0.238$).

	AR(2)	SARMA(2,0)(1,0)$_{16}$
s^2	0.091	0.082
V_e	62%	**65%**

Table 3. The goodness of fit of the models estimated for metrical stress series

The results clearly indicate that both the quantity series and the stress series constitute realisation of stochastic processes. In both cases, the models identified prove relatively effective in that they manage to explain a considerable percentage of the original variance. The variance of the stress series is explainable to a greater extent (65%) than that of the quantity series (53%). Again, in both cases it was the seasonal models that worked better, although the increase in explanatory power is more considerable for the quantity-based series.

SUMMARY RESULTS

Analysis of the other samples corroborates the above findings. The average values of V_e are 50% for the quantity-based series and 63% for the *ictus*-based series and do not diverge from those obtained in the case study. For the vast majority of the samples, the seasonal models proved more effective than simple ones, especially in the case of the quantity-based series.

Since V_e can be taken to be a measure of a text's rhythmicity, it is not difficult to arrive at a linguistic interpretation of the results: the stress-based series are more rhythmical than the quantity-based series. This can be taken as an argument in favour of the reality of *ictus* in Greek hexameter.

What is harder to interpret linguistically, however, is the explanatory power of seasonal models for the quantity-based series. Presumably, there is a link between the value of the seasonal component ($s = 16$) and the average length of a line in the sample (16 syllables). This might mean that in Greek hexameter, quantity is a stabilising factor in that it makes equivalent verses roughly equal in length.

CONCLUSION: GREEK VS. LATIN HEXAMETER

Examination of samples of the *Iliad* corroborated the hypothesis that dynamic metrical stress was probably a real feature of Greek hexameter as well as a major determinant of text rhythm at syllable level. Quantity, on the other hand, has been shown to play an important role in determining text rhythm at verse level. The results suggest that the memorisation and performance of Greek epic poetry were based on these two prosodic features.

Our conclusions will become more convincing if we compare the results with our earlier analysis of Latin hexameter[48], in which the same method was used to examine samples from Horace, Virgil, and Ovid. The percentage of the original variance explained by the optimal models proved much lower for the Latin samples than for the Greek ones (15% for quantity- and 61% for stress-based series, while in the *Iliad* respectively 50% and 63%).

	quantity	metrical stress
Latin hexameter	15%	61%
Greek hexameter	53%	65%

Table 4. The average rhythm of Latin and Greek hexameter (V_e values)

Contrary to the results for the Greek samples, no significant improvement in effectiveness was noted when seasonal models were used to analyse Latin material. This means that the rhythmicity of the Latin samples (with regard to the quantity) was much less noticeable than that of the *Iliad* samples. Such a wide divergence may have at least three explanations. On the one hand, the Latin verse (and the Latin language in general) is very rich in long syllables, as compared with Greek[49], and this fact may influence rhythmicity of hexameter. On the other hand, the obtained results seem to reflect the fact that the Latin hexameter, and Latin versification in general, was an implantation of Greek verse system: being quite natural within the cultural and linguistic context of Greek, the prosody of hexameter would lose much of its inherent rhythmical properties in Latin. Last but not least, the divergence may also provide a clue that rhythmicity of Greek hexameter appeared in a natural way as an aid to memorisation of oral texts, but it played a lesser role in Latin epic poems, which belonged initially to the written register. To test this conjecture, further research is needed in two areas: the

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[48] Pawłowski, Eder 2001.

[49] Raven 1998: 31.

comparative study of oral texts in Greek and Latin, and the contrastive analysis of Greek oral and written texts.

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