The Principles of Structural Unit Separation for Deciphering the Neume Hymnals

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Abstract

The problem of translation of Russian ancient hymnals from the neume notation into the modern note form which is unsolved in the general case, is considered. In view of the context dependence on the neume hymnody (znamenny raspev) language the "neume-note" correspondence is a multiform. Because of this, it is desirable to choose not the individual neumes as the deciphering units but the larger structural units with lesser ambiguity. Different criteria and algorithms of such unit separation from the hymnal text written only in neume notation or in neume form and note form in parallel are suggested.

INTRODUCTION

The ancient Russian hymnals of XII-XVII centuries are mainly presented in the neume written form. The neumes are special signs (graphemes) using for denoting musical sounds. They are interpreted as note sequences of different lengths (usually from 1 to 5 notes). The process of hymn translation from the neume form into the note writing form called the deciphering process was not yet formalized in the general case and because of that the hymnal manuscripts of XVI-th century and those of earlier period are not deciphered and, according to academician D.S.Likhachev, they belong to the "culture of silence". Only a few examples of deciphering, the so-called "marked" manuscripts of XVII-th century, where the neumes are accompanied by special marks, are known (see Brazhnikov 1974). In these cases, the deciphering process is facilitated much by the presence of the degree and indicative marks defining the high-pitch orients and the character of individual neume singing. Actually, the problem of deciphering the ancient Russian neume hymns is analogous to a similar problem for Byzantine hymns but this

similarity is only valid for the early slavic chant (X-XII centuries) (Velimirovič 1960).

To decipher the later manuscripts there are used the "marked azbuki" – collections of "neume-note" correspondences created by the well-known Russian experts of neume hymnody - V.M.Metallov, S.V.Smolensky and P.V.Razumovsky - and also "kokizniki" - the collections of popievki – elementary intonational units of neume hymns (chant) i.e. the melodic motives characteristic of the ēchoi[1]. These are the stable melodic fragments occurred in the process of evolution of melodic formulae, which were the basis of the Byzantine chant (Preobrazhensky 1926). The "azbuki" and especially "kokizniki" are of different volume, sometimes contradictory and present not the entire spectrum of structural units and are little of use for the deciphering of the neume manuscripts without "marks". In this connection, the detection and systematization of structural units directly using the texts of hymns is quite important and this is purpose of this work.

The separation of structural units from the text is reduced to the development of a set of criteria which formalize the concept "elementary semantic unit" and to the development of effective algorithms realizing these criteria. Some of these criteria are of general-linguistic character (frequency-positional criteria), the other ones account for the specificity of the neume hymns.

1 The basis of Project

To our point of view the main difficulty of deciphering is connected with the fact that the language of znamenny raspev is *context-dependent*. It manifests itself in the fact that the interpretation of individual neumes depends on the type of elementary structural units including these neumes as their integral part, also on the position of these units in hymn melody, on the ēchos belonging, and on some other factors providing the multiform character of "neume-note" and "note-neume" correspondence. For example, the neume

 ("statja with comma") appears twice in popievka "kavychka"

[1] The eight ēchoi of the Byzantine oktoēchos were divided into four authentic and four plagal (derived) modes. The Russian ēchoi show a different structure and the system of popievki became the melodic motives characteristic of the ēchos.

from 6-th ēchos:  ; in the third position it is interpreted by chain from three notes: *e2d2c4* and in fifth position, one note *d1* (below, the notes of the first octave are coded by capital letters: *G* – sol, *A* – la, *H* – si; the second octave – by small letters: *c* – do, *d* – re, *e* – mi, *f* – fa, *g* – sol, *a* – la, *h* – si, *b* – flat si and the figures from the right indicate the duration of note: *1* – whole, *2* – half, *4* – quarter etc.).

Because of the language context dependence, it is reasonable to use not the individual neumes as a deciphering units but larger structural units ("neumes in context") with the minimum possible degree of ambiguity.

The basis of suggested approach is:

1) the automatic *separation* of structural units from the unified neume text not splitted earlier. Note that the availability of the note text and the sequence of special marks can facilitate the separation of structural units but we do not use them at all, because of their absence in the general case. The dvoznamennik is only necessary at the stage of interpretation of separated structural units.
2) The interpretation of separated structural units with the use of *dvoznamenniks* . Dvoznamenniks are bilingues of neume hymns i.e. the texts presented both in the neume and in the note form in parallel.

Below we consider in more detail the suggested criteria of structural unit separation.

2 CRITERIA OF STRUCTURAL UNIT SEPARATION

2.2 Frequency criterion (Bakhmutova, Gusev, Titkova, Shindin 1994) is based on assumptions that the elementary semantic units of language appear as steady repeating chains of symbols. The concept of stability requires more precise definition.

Let $a_1 a_2 \ldots a_n$ be an arbitrary chain (word) from text *T* composed from the elements of alphabet Σ. For all possible prefix sub-words of this word the following relations hold:

$F(a_1) \geq F(a_1 a_2) \geq \ldots \geq F(a_1 a_2 \ldots a_{n-1}) \geq F(p)$, where $F(\alpha)$ is a frequency of occurrence of the word α in the text *T*. We shall call the chain *p* stable for the right-hand extension (or stable to the right) if:

1) there is $1 \leq i < n$, such that
   $F(a_1 a_2 \ldots a_i) \hbar F(a_1 a_2 \ldots a_i a_{i+1}) \hbar \ldots \hbar F(p)$, where sign "$\hbar$" denotes "not much more or equal" (this is condition of appearance of frequency dominant line);
3) $F(p) > 1$;
4) $F(pa_{n+1}) = F(a_1 a_2 \ldots a_n a_{n+1}) < F(p)$, where $a_{n+1} \in \sum$ and pa_{n+1}- an arbitrary chain from text *T*.

The first condition means that as soon as the forming chain acquires meaningful sense its continuation is easily predicted , i.e. the frequency of chain $a_1 a_2 \ldots a_i a_{i+1}$ in text *T* dominates over the frequencies of chains $a_1 a_2 \ldots a_i \alpha$ $(\alpha \in \sum, \alpha \neq a_{i+1})$, realizing other possible extensions. (The word "champion" for example, is predicted already by chain "champi"). The second condition eliminates all the chains with *F=1*, as any their extensions have the same frequencies and formally are indivisible. The condition (3) corresponds to the break of frequency dominant line fixed by conditions (1) and (2) (the word "champion" may be prolonged in different ways, since each prolongation contains the initial word, the frequency of any of them is less than the frequency of initial words).

Similarly, the chain $p = a_1 a_2 \ldots a_n$ from text *T* we shall call stable with respect to the left-hand extension (stable from the left) if there is $1 < j \leq n$ such that
$F(a_j a_{j+1} \ldots a_n) \hbar F(a_{j-1} a_j \ldots a_n) \hbar \ldots \hbar F(p)$, $F(p) > 1$,
$F(a_0 p) = F(a_0 a_1 a_2 \ldots a_n) < F(p)$, $a_0 \in \sum$, $a_0 p$ is an arbitrary chain from text *T* . The potential *structural unit* will be considered as the chain of symbols stable both from the left and right. This is a fragment placed in between the left and right break points of frequency dominant line.

The algorithm of structural unit discovery reminds the "swing". Starting from any alphabetic element (or chain of elements) we

analyze all possible prolongations in search for frequency stabilization localities. After fixing the right boundary we proceed the other way in search for the left boundary. It is possible that in the first pass the right boundary is not fixed (the zone of frequency stabilization does not manage to show itself because of that the starting chain was very close to the right boundary). Returning to the initial chain, we realize the left-side extension. After fixing the left boundary we again proceed to the right (the second pass) in search for the right boundary (whence the term “swing”).

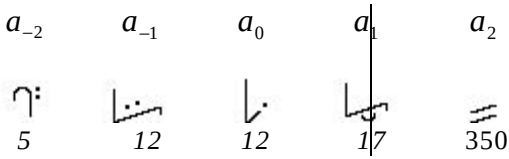
To receive the frequencies of all possible sub-chains we calculate preliminary the full frequency spectrum of *l*-grams from text $\Phi(T) = \{\Phi_l(T)\}$, where $\Phi_l(T)$ - the frequency characteristic of order *l*, $1 \le l \le l_{\max}$, $l_{\max}$ – the length of longest repetition in text. $\Phi_l(T)$ contains the information about all repetitions of length *l* from *T*. Here $T = T_1 * T_2 * \ldots * T_m$ is concatenation of hymns from one ēchos , *m* is the number of hymns, ‘*’ is a separator but the repetitions without ‘*’ are only considered. For calculation of $\Phi(T)$, the procedure of recurrent hash-coding is used (Gusev, Titkova 1994).

Let us demonstrate all said above by an example of the chain 

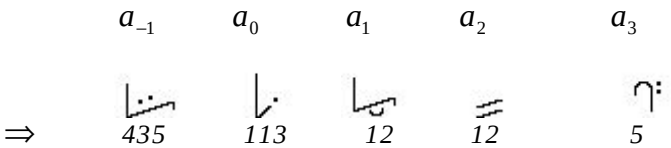
 $(l = 2, \quad F = 17)$ from 8-th ēchos (“Oktoēchos ”, XVII century, Kirillo-Belozersky collection, 632/889, in Manuscript Department of the National Library of Russia in St. Petersburg). For the sake of simplicity, we shall consider the right-side extensions of this chain as frequency dominant and trace the changes of frequencies $F(a_1)$, $F(a_1 a_2)$ etc.:

	a_1	a_2	a_3	a_4
$\Rightarrow$				
	38	17	7	2

Here the number in the lower line under the symbol "a_i" denotes $F(a_1 a_2 \ldots a_i)$. It is easy to see that with the extension of chain to the right there is no stabilization of frequencies. Let us return again to the initial chain and try to extend it from the right to the left tracing the frequencies $F(a_2), F(a_1 a_2), F(a_0 a_1 a_2)$ etc.

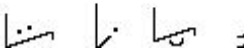


It is seen that in this case, there is a zone of frequency stabilization (17, 12, 12) which terminates at the shift to the neume a_{-2}. We put the left boundary between a_{-1} and a_{-2}. Then beginning from a_{-1} we pass again from the left to the right in the search for the right boundary:



And in this case, we see also that the zone of frequency stabilization (12,12)

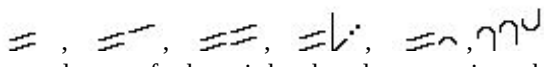
that terminates when passing to a_3. We put the right boundary between a_2 and a_3.

The potential semantic unit is the chain  *(F=12)* located in between the left and right boundaries. This is popievka from the family of "kokiza" .

The approach described above separates well the most mass popievki of ē*chos* and also some structures that do not belong to the category of popievki. However, this approach fails in short low-frequency popievki where there is no zone of frequency stabilization and the concepts of "much larger" ($>>$) and "not much larger" ($\hbar$) and etc. loose their sense.

2.3 The fequency- positional criterion (Bakhmutova, Gusev, Titkova,, Shindin

1997) removes some disadvantages of frequency criterion and accelerates substantially the search for the structural units. The idea of the approach reduces to that by using some a priori information about neumes and also the relationship between verse and neume texts it is possible to reveal a set of neumes *terminating* popievki (

 etc.). As a result, the procedure of the right- hand extension becomes unnecessary. All appearances of each cadence (final) neume in text are detected in turn. The chains preceding them and read from the right to the left are packed in lexicographic tree with sewn common origins (they correspond to the popievki ends). The cadence neume is the tree root. The left ends of popievki are fixed as the boundaries of frequency stabilization zones in moving from the root to the leaves. *The low- frequency* (and as a rule short) tree chains can be identified *by analogy* with neighbo uring high- frequency ones.

The disadvantages of this approach are: the possibility of cadence neume omission at the stage of neume set formation consisting from the concluding popievki, the possibility of cadence neume

occurrence not in the final part of popievka (see neume in the position of popievka “kavychka” in section 1) and the aim of the whole approach is only the structure like “popievka”.

2.4 The detection of high- pitch invariants

In contrast to the previous approaches this one principally requires the presence of dvoznamenniks. The analysis of frequency characteristics $\Phi_l(T) \quad 1 \le l \le l_{\max}$, shows that the multiformity of correspondence “neume – note” is not of absolute character. The individual neumes and more often the chains of neumes allow within one ēchos (and sometimes within several ēchoi) the unique interpretation. They can serve *the high- pitch orients* in deciphering *manuscripts without marks* .

So, the analysis of dvoznamennik —“Oktoēchos ” of XVII- th century, Solovetsky collection ~~sh~~owed that in glases 1, 2, 4, 6 the neume

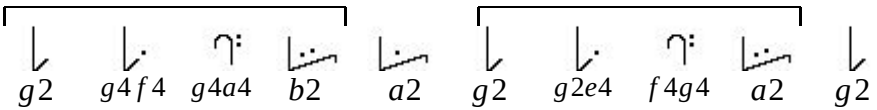
 ("strela svetlaya") is interpreted uniquely code *e4f4g2* and in

glases 3, 4 - ("derbitsa") – code *H4c4d4e4* and etc. The property of unique interpretability evidences the high *informativity* of corresponding neumes or chains since in all language systems the fragments of text not changing in the course of the evolution are believed to be the most significant functionally. The number of uniquely interpreted chains grows with the increase in their length. A disadvantage of the approach is the ignoration of low-frequency though uniquely interpreted chains since their "uniqueness" can be a random factor (a consequence of low frequency).

2.5 The tandem repetition quite regular in neume hymns can be also referred to

the class of structural units not included into the conventional deciphering tables. In the simplest case, we deal with the series

formed by repetition of the same neume (series of "stopits" () corresponding to the recitative fragments, series of "kryuks" etc.). In the general case, we deal with tandem repetitions of chains of length $L \geq 2$ composed from different neumes. They need a special study since the repeated fragments are not always interpreted identically:

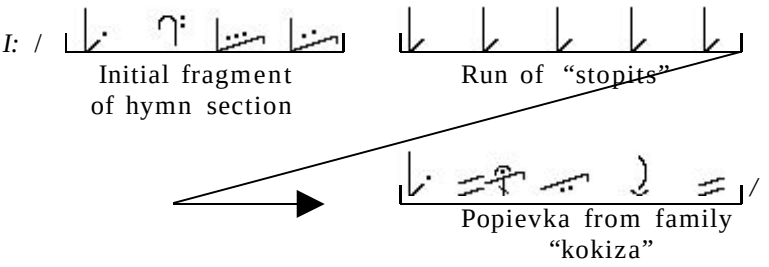


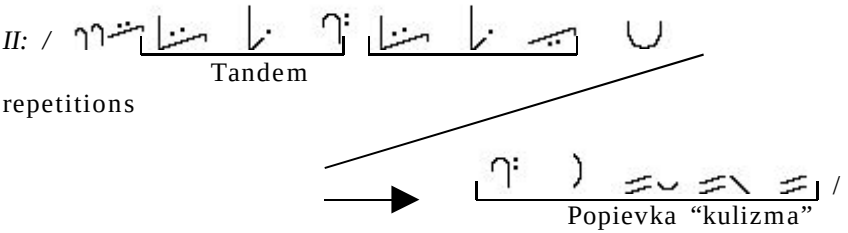
The status of tandem repetitions as the independent structural units is confirmed by an analysis of the intraēchos repetitions with maximal length that will be discussed below.

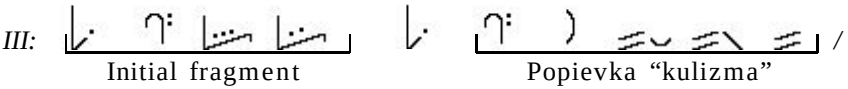
2.6 The longest repetitions in ē*chos*

They are usually formed by the fragments presented in different hymns of the same genre. Their lengths are large enough (from 10 to 20 neumes) that says about non-random character of these repetitions. The longest non-random repetitions are interpreted in many language systems as independent structural units.

The longest repetitions in hymns are interesting since they are the concatenations of the smaller structural units. These units can be separated as the common parts of the longest repetitions. Let us illustrate this by the example of the following three repetitions from the second ē*chos* (“Oktoēchos ”, Kirillo- Belozersky).







Here the sign (/) corresponds to the pause in verse text which usually correlates with the music pause. The frame of repetitions I, II and (partially) III by the sign (/) emphasizes the completeness and independent status of these units. It is simple to see that the pairs I, III and II, III contain the common chains (underlined in figure). These units are of the lower hierarchy level.

The method of structural unit separation by the longest repetitions is simple and visual. The disadvantage of this method is that separated unit set is limited (not all of them are a part of the longest repetitions). However, the typical initial fragments, a set of which is not large, are separated completely enough whereas the frequency criterion can fail because of their small length and instability.

CONCLUSION

The problem of the translation of Russian ancient hymns from the neume notation into the form of modern note one is considered. In spite of its Byzantine origin the neume hymnody evolved so that it is not yet possible to use the results of the readable Byzantine hymn manuscripts analysis directly for deciphering Russian ancient hymns.

To our point of view, the main difficulty of deciphering is connected with the context dependence of neume hymn language. In this connection, the problem of optimal unit choice for deciphering is very important. The different criteria and algorithms for the structural unit separation from the texts of hymns are suggested. They mutually supplement each other. The spectrum of separated structural units is substantially larger than that presented in the known deciphering tables made by hand. It is suggested that the use of these structural units for a deciphering purposes will produce the essential decrease in ambiguity in comparison with the deciphering by individual neumes.

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