

A Systematic Comparison of Different European Folk Music Traditions Using Self Organizing Maps

Zoltán Juhász

Research Institute for Technical Physics and Materials Science.

P.O.B 49. Budapest H-1525.

e-mail juhasz@mfa.kfki.hu

Abstract

The relations of six European musical cultures were investigated using self organizing mapping of the melody contours. The high number of contour types characterizing more than 2 cultures simultaneously led to the supposition of a hypothetical common musical language, and the corresponding contour types were determined using a self organizing map, being able to “understand” the six cultures in parallel. The analysis showed that significant parts of the common language are represented in the six national cultures, and it exists practically completely in Hungarian and Slovak folk music. The mapping of the melody sections and the contour types of the common language to a multidimensional “melody space” resulted in a clear musical description of the contacts, thus, the hypothesis of an archaic common musical tradition in Europe seems to be worth considering.

1. Introduction

Hearing folksongs of different nations, the listener can be deeply impressed by the rich variety of composing principles assuring special colors of oral musical traditions. Some particular features of different cultures can be clearly identified by certain typical melody forms on one hand, but other melody types may show close relations between them, on the other hand. A systematic study revealing the most important musical connections as well as differences between different national cultures requires the comparison of thousands of melodies one by one, thus, the use of computer can significantly facilitate a more or less comprehensive description. The idea of computerized analysis and classification of folksongs arises from the 60-ths, but the development of efficient methods started a few decades later (Csébfalvi, Havass, Járdányi, Vargyas, 1965), (Rhodes, 1965).

Current computing methods are usually focused on one particular musical characteristic. When studying folk music, the most general aims are segmentation, contour analysis and classification using different statistical characteristics, e.g. interval distribution or rhythm distribution. A large amount of German and Hungarian folksongs has been studied with the aim of separating typical motives in the melodies (Bod, 2001a; Bod, 2001b), (Juhász, 2004). A method based on dynamic programming has been successfully applied to characterise the diversity of the contours using dynamic programming (Sachira and Milan, 1997). A systematic description of Hungarian folk music in a multidimensional space was also based on the study of the contour, using principal component analysis (Juhász, 2002). Principal component analysis has also been applied for timbre characterisation (Sandell, 1995). Neural networks and self organising maps were used for classification of certain musical statistics of

Finnish folk music, as well as the musical timbre (Toiviainen, Kaipainen and Louhivuori, 1995; Jarvinen, Toiviainen and Louhivuori, 1999; Toiviainen 1996; Toiviainen, 2000; Toiviainen, 2001; Krumhansl, 1999, Krumhansl, 2000, De Poli and Pradoni, 1996). Self organising maps have also been applied in a complex model of human music cognition (Leman, 2000).

In the present work, we describe a method estimating the most typical contours of some European oral musical traditions using self organising maps. It follows from the principle of self organising maps that similar contours are situated close to each other after training, consequently, the final topology provides us a visual representation of the main musical connections. However, an accurate musical interpretation of such a map is rather problematic, since the exact relation between spatial and musical features is not defined. Therefore, we represented the original melody contours and those of calculated by the self organising map as “types” in a multidimensional “melody space”. We have shown in a previous work that the spatial characteristic of the point system representing melody contours in the above-mentioned space can be well interpreted from musical point of view.

Using the above techniques, we wished to continue a work that began in the early 60s, with the aim of studying European relations of Hungarian folk music. To do this, representative collections of different folk music cultures have been digitized at that time (Csébfalvi, Havass, Járdányi, Vargyas, 1965). As a result of this work, representative digital data bases of Slovak (1940 melodies), French (1480 melodies), Sicilian (1380 melodies), Bulgarian (1040 melodies) and Appalachian English folksongs (880 melodies) have been generated. The literal sources of the above data bases are representative collections themselves (Slovenské Ludové Piesne, 1950; Canteloube, 1951; D’Harcourt, 1956; Favara, 1957; Stoin, 1931; Sharp,

1932). Further folk-music collections have also been digitized, but we focused our work on the largest data bases, counting more melodies than an appropriate limit (800). The Hungarian digital data base has been built in the 90s, based on the work of Dobszay and Szendrei, characterizing Hungarian folk music using 2323 “Old Hungarian Folksong Types” (Dobszay, Szendrei 1992). This work can be regarded as a summary of the results of an extensive project for classifying Hungarian folksongs (Járdányi, 1974; Dobszay 1978; Szendrei 1978; *Corpus Musicae Popularis Hungaricae* 1951-1997).

The studied collections consist of vocal melodies, therefore, their sectional systems are well defined by the texts. This made us possible to select the level of the analysis – that is either comparing whole melodies to each other, or sections treated as stand-alone entities. We found that very characteristic regularities can be identified at the level of sections, but the variety of whole melodies seems to be too large to find simple and characteristic structures at this highest level. Therefore, we studied sections separately.

Firstly, we determined self organising “contour type maps” for the six cultures one by one, and compared the six maps to each other. However, the high level of overlapping of the section contour types raised the idea to determine a hypothetical “common language”, and investigate the relation of the musical cultures to this hypothetical musical system.

2. Melody vectors

The generation of vectors from melodies has been detailed in previous works, but it is also summarised in Figure 1, showing the first section of a Hungarian folksong as an example.

Firstly, we defined the continuous pitch-time function, which is represented by the thick line in Figure 1. There, the pitch is characterised by integer numbers, increasing 1 step by one semitone, zero level of the pitch corresponding to the C tone. One can see in the figure that the duration of the temporal intervals of the pitch-time function is determined by the rhythmic value of the corresponding note. Thus, the main rhythmic information is also encoded. For sampling, the total length of the pitch-time function was divided into D portions, where D is the dimension of the music space. Then, the “melody vector”,

$$\underline{x}_k = [x_{1,k}, x_{2,k} \dots x_{D,k}]^T \quad (1)$$

was constructed from the sequence of the pitch-time samples of the k th melody. These melody vectors \underline{x}_k are interpreted in the D dimensional “melody space”, which is founded by the orthogonal “sampling basis” as follows: The first axis corresponds to the first pitch sample, the second axis to the second pitch sample, and so on, up to D . In this basis, the melody vector of the k th tune is represented just by the co-ordinates $x_{1,k}, x_{2,k} \dots x_{D,k}$ of \underline{x}_k in Equation (1).

Since D was uniform for the whole set, melodies could be compared to each other using a distance function defined in the same D -dimensional melody space, independently of their individual length. (Thus, the sampling time was determined for each melody individually, depending on the actual time duration.) The greatest advantage of this technique is that melody contours can be compared independently of their measure, tempo and syllabic structure. We found that a choice of $D = 32$ resulted in an appropriate accuracy for each melody, when investigating single sections.

To assure uniform conditions, each melody was transposed to the final tone G, and four classes of sections were defined, as follows. Every melody has first and last sections. (Melodies of one section were selected into the group of first and last sections alike.) Every melody having more than 2 sections, has second and before-last sections. (Second sections of melodies with 3 sections were considered both as second and penultimate ones.) It follows from the above categorisation that certain sections of melodies having more than four sections were not analysed. Since the study has shown that the most variegated sections are usually the first ones, and the results are consistent in the four selected groups, we supposed that the analysis of the remaining sections would not modify the results significantly. The most important contour types of the different cultures were determined for the four groups of sections separately, using self organising maps.

3. Determination of contour types using self organising maps

To calculate the most typical contours, we defined a grid of $G \times G$ size, and assigned $D=32$ dimensional “contour type” vectors $\underline{c}_{i,j}$ to the intersections (i, j) . Typical melody contours were determined by training the map with defined groups of the melody vectors \underline{x}_k (see Figure 2). After training the map with the melody vectors of a given culture, the resulting contour type vectors $\underline{c}_{i,j}$ represent the most important contours characterising the given culture. In other words, the studied cultures can be characterised by their own contour-type maps, and the relations between different cultures can be investigated comparing contour types instead of concrete melody sections. Since the number of contour types is defined by the grid size, the problems arising from the different sizes of the different national data bases can also be solved when using contour types for comparison.

The particularities of the studied data base used to be taken into consideration when defining the “distance” function applied in the algorithm (Kohonen, 1995; Toivainen, 2000). When studying melody contours, the question can be raised, whether all of the D=32 vector elements of a contour vector are equally “important”, or not. It is easy to see that the beginning and ending parts of a melody section may be more “important” than other parts, but other special features of the contour types may be defined by other “important” parts, too. Furthermore, the “importance” of a given part of the D=32 dimensional contour type vectors may depend on the contour itself. Based on the above reflection, we defined a distance function using adaptive weights for the D=32 vector elements. The distance between a “melody vector” and a contour type vector was defined as

$$\Delta_{i,j} = \sqrt{\underline{\mathbf{d}}_{i,j}^T \underline{\mathbf{S}}_{i,j} \underline{\mathbf{d}}_{i,j}}, \quad (2)$$

where $\underline{\mathbf{d}}_{i,j} = \underline{\mathbf{c}}_{i,j} - \underline{\mathbf{x}}_k$ is the difference vector of the contour type vector assigned to location (i, j) and the “melody vector” representing a given section contour. The importance of the 32 elements of the contour type vectors was defined by the diagonal weight matrix

$$\underline{\mathbf{S}}_{i,j} = \begin{bmatrix} s_{i,j,1}, 0, \dots, 0 \\ \vdots \\ 0, \dots, 0, s_{i,j,D} \end{bmatrix}. \quad (3)$$

Thus, all of the G*G locations of the map had their own adaptive weight matrix. During training, the matrix elements $s_{i,j,l}$ approached 1 at positions where the difference between the

contour type and the fitting section contours was usually small, and 0 at those positions where the difference was usually large.

The training algorithm can be summarised as follows:

In the initial state, the $\underline{c}_{i,j}$ vectors were filled with random numbers. The initial value of the weights was $s_{i,j,l} = 1$ for any diagonal elements of the weight matrices. The size of the grids varied between 12*12 and 18*18. The initial value of R was the half of the grid size, and it was decreased to R=0,9.

1. A melody section of the data base was selected randomly and its melody vector \underline{x}_k was compared to the typical contour vectors $\underline{c}_{i,j}$ using the distance function defined in Equations (2) and (3).

2. The intersection (m,n) of the minimal distance $\Delta_{m,n}$ was determined. The $\underline{c}_{i,j}$ vectors assigned to intersections inside the circle of radius R around intersection (m,n) were modified using

$$\underline{c}'_{i,j} = \underline{c}_{i,j} + \lambda \Delta_{i,j} (\underline{x}_k - \underline{c}_{i,j}) , \quad (4)$$

where λ is a scalar factor controlling the rate of convergence and the accuracy. To avoid boundary problems when determining the surroundings of location (m,n) , we applied periodical boundary conditions.

3. The diagonal elements $s_{i,j,l}$ of the weight matrices belonging to the locations around intersection (k, m) were increased when the difference vector element at the l -th position of the 32 dimensional difference vector $\underline{d}_{i,j} = \underline{c}_{i,j} - \underline{x}_k$ was less than a threshold value δ :

$$s'_{i,j,l} = s_{i,j,l} + \gamma(1 - s_{i,j,l}) \quad |d_{i,j,l}| < \delta, \quad (5)$$

and decreased otherwise:

$$s'_{i,j,l} = s_{i,j,l} + \gamma(0 - s_{i,j,l}) \quad |d_{i,j,l}| \geq \delta. \quad (6)$$

The rate of convergence was controlled by the scalar factor γ .

4. The radius R was decreased linearly until it reached R=0.9.

We determined contour-type maps for all of the 6 cultures and for all of the 4 sections (first, second, penultimate and last sections). Thus, we determined $6 \cdot 4 = 24$ maps. After training, the maps were “excited” with the section contours, what means that all of the sections were compared to the contour types of the corresponding map, using Equations 2 and 3. The location of the minimal distance (m, n) was determined, and the studied section was classified as a member of the group belonging to the typical contour at location (m, n) , on condition that the resulting minimal distance was less than a threshold value of the diversity ε , being equal for the 24 maps. The number of successfully classified sections $v(i, j)$ was determined for all of the locations on the grids. From these data, we calculated the “classification-distributions”

$$f(N) = \frac{1}{M} \sum_{i=1}^G \sum_j^G v(i, j), \quad N \leq v(i, j) \quad (7)$$

for each map, as the relative number of melody sections classified on locations having more than N classified sections. M is the total number of melodies in the collection.

The classification distributions allowed us to compensate the effects of different data base sizes. The number of melodies in a collection representing a musical culture depends on the number of melody types in the corresponding culture, and the average number of the variants characterising a type in the collection. The former condition is defined by the culture itself, but the latter depends on the decision of the author, therefore, the number of really existing types in a collection is unknown – it must be estimated by fitting the size of the self organising map to the real conditions of the collection. (We supposed that all important melody types of the studied musical cultures are represented in the corresponding collections.) It is easy to see that a low map size may lead to an under-estimated number of contour types, what results in a low rate of successfully classified melodies $f(1)$. Consequently, $f(1)$ can be increased by increasing the map size. Thus, fitting the map sizes of different collections using the requirement of minimal difference of the corresponding classification distributions assures equal conditions to estimate the number of really existing contour types for each collection. Comparing the resulting contour types instead of melody sections really compensates the disturbing effect of the above problem.

Figure 3a shows classification distributions of maps with a size of 12*12 locations. The curves show that 80-90% of the first sections of five cultures was successfully classified, but less than 70% of Hungarian tunes could be classified under the same conditions. The

relatively slow decrease of this latter distribution with increasing N shows that Hungarian types are “overfilled” compared to types of other cultures. It follows from these data that Hungarian first sections need a map of larger size. Really, Figure 3b shows that the distribution of a $16*16$ map of Hungarian first sections fits much better to other curves. Generalising the above consideration, we equalised the differences arising from the different sizes of the data bases and from the different number of really existing contour types of different cultures by fitting map sizes to the requirement that the number of the successfully classified melodies must be inside a defined interval for $N \leq 2$:

$$0.8 \leq f(1) \leq 0.9 \quad 0.8 \leq f(2) \leq 0.9 \quad (8)$$

for any section of the 6 cultures.

4. Comparison of musical cultures

After training with melody contours of one given musical culture, the self organising map represents an abstract “musical language”, which is optimal for “understanding” melodies of its own musical culture. Using the terms of neural networks, the contour type vectors $\underline{c}_{i,j}$ function as “receptors”, “firing” or “being activated” when a melody contour is found to be close enough to them. To compare two different “musical languages”, one of them shall be “excited” by the contour types of the other language. Common musical features can be identified by contour types being activated by types of the foreign language, and particular characteristics are also described by those having no relations in the other culture. A complete comparison requires the excitation of both languages with the other one.

The results of a systematic comparison are summarised in Figure 4. The grouped columns in Figure 4a show the relative number of contour types of the language indicated on the horizontal axis, activated by contour types of the 6 languages. For example, the third group shows that the ratios of French contour types activated by Hungarian, Slovak, French, Sicilian, Bulgarian and Appalachian English types are 0.85, 0.79, 1.0, 0.53, 0.34, 0.57 respectively. The close contact between musical cultures in the Carpathian Basin is indicated by the fact that Hungarian and Slovak types are mutually the most activating for each other. A more surprising lesson of the systematic comparison is that the mentioned cultures are the most activating ones for any of the studied cultures. French and Appalachian English contour types are also rather activating for each other, thus, significant contacts of these cultures are also indicated by the maps. The same data are grouped in Figure 4b from another point of view. Here, the grouped columns show the ratio of types of different cultures excited by the language indicated on the horizontal axis. The groups of Figures 4a and 4b are averaged in Figure 4c. The left columns show the mean ratio of foreign types activated by the language indicated on the horizontal axis, the right columns represent the mean ratio of the types activated by foreign languages. The right columns show that usually more than a half of national types are activated by foreign languages, except Hungarians, where this ratio is less than 0.45. This result indicates a significant amount of non-European types in Hungarian folk music. It is also very interesting that the most “excitable” culture is Slovakian, in spite of the close connections with Hungarian folk music. A further interesting lesson of Figure 4c is that the most “exciting” culture is Hungarian, for all that it is the less “excitable”.

The high number of “receptors” activated by another languages indicates close connections between European musical traditions. Are the common features of different musical traditions

occasional, depending on the couple of cultures being compared, or general, caused by a common set of contour types being found in more European cultures? This question can be investigated by determining contour types of a hypothetical “common language”.

5. The common language

To find a “common language” being optimal for “understanding” the studied cultures simultaneously, we trained a self organising map with all contour types of the six cultures. Since the inequalities of the data base sizes were equalised, the training assured equal chances for any national contour type (see Chapter 3). It follows from the training algorithm that similar melody lines being typical in more than one cultures were averaged as one contour type of the “common language”, while particular forms had less chance to find a common type. Thus, the “common language” is not a set of contours being found in all of the six cultures, much rather an optimal union of the contours existing in more than one musical languages.

Exciting the resulting map representing the types of the “common language” by the six national languages one by one, we determined the relative numbers of activated receptors of the common language. (The six maps showing the number of national types corresponding to different locations of the common language are represented in Figure 8b.) We also determined the ratios of national types activating the common language. Figure 5a shows the relative numbers of the receptors of the common language being activated by the national languages, which latter are indicated on the horizontal axis. The groups of columns show the results section by section. The reason of the relatively low level of Sicilian and Bulgarian second and

before-last sections is the high ratio of melodies having two sections of these musical cultures. Figure 5b represents the relative numbers of national types activating the common language. The low level of the third column of the Appalachian English group shows very particular structures of before last sections in this culture. The averages of the national groups of sections are summarised in Figure 5c. The left columns show the average ratios of common language types being activated by national languages, while the right ones show the rate of national types activating one of the common receptors.

According to Figure 5c, Hungarian types excite more than 90% of the common language. At the same time, less than 50% of Hungarian folksong sections are related to a common type. In other words, more than 90% of the common language is represented in less than 50% of Hungarian folk music, thus, the common language is a significant, but not dominant part of it. By all means, the most complete representation of common European types is found in Hungarian folk music.

The common language is activated by still less Appalachian English types (40%). However, this low amount of national types activate more than 60% of the common language, which fact shows that Appalachian English folk music holds a significant part of it, but other types represent some particular features.

Slovakian folksongs activate almost as much common types as Hungarians (more than 80%). Considering the close connections between Hungarian and Slovak folk music, this result is not surprising (see Figure 4). However, an important difference between Hungarian and Slovakian folk music is also shown by the results, since this high amount of common types is represented by a relatively high amount of Slovakian types (more than 70%). This shows a

mutual connection between Slovak folk music and the common language, in spite of Hungarian folk music, where the connection is more one-directional.

The less types of the common language are stored in Bulgarian folk music, because of the dominance of melodies of low ambit in this culture. Our method generating pitch-time functions and multidimensional “melody vectors”, is not sensitive on rhythmical movements evaluated on constant pitch level. Therefore, the very rich rhythmical variety of Bulgarian folk music – which may be in connection with the low ambit – should require another kind of analysis. At the same time, the contacts with the common language are shown by the high ratio of Bulgarian types activating common receptors (more than 65%).

The results show that the common language is represented in all of the studied cultures in significant degree. The common types are mostly represented in the Carpathian Basin, as a significant but not dominant part of Hungarian, as well as a dominant part of Slovakian tradition.

Up to this point, the method of self organising mapping allowed us to interpret contacts of musical cultures without any analysis of concrete musical relations. However, a clear musical interpretation of the results is unavoidable. To do this, it would be possible to give a long list of contour types of the common language, and some examples of melodies belonging to these types. Although the topology of the self organising maps is determined by the relations of the melody contours, it would be very complicated to attribute an overall and clear musical interpretation to this topology, to clarify connections of the different contour types. Therefore, we base the interpretation on another principle of mapping, which is able to clarify the main musical relations of contour types and section contours.

6. A musical interpretation - mapping of contours to the melody space

As we have mentioned in Chapter 2, the $D=32$ dimensional melody vectors \underline{x}_k , defined in Equation (1), are interpreted in the D dimensional “melody space”. This assignment yields a mutually unambiguous mapping of each melody section to a point in the melody space, thus, main features of different musical cultures can be studied as spatial regularities of the corresponding multidimensional point systems.

We have shown in a previous work that 32 dimensional point systems representing melody sections of Hungarian folksongs can be approximated in a low-dimensional subspace, and a very clear musical meaning can be attributed to the orthogonal basis vectors determining this subspace (Juhász, 2002). According to Figure 6, these basis vectors divide the melody sections into 3 parts: First, second and third basis vectors stand for the main pitch level at the beginning, ending and central parts of the sections, respectively. We visualised the point systems by projecting them to the plain founded by the first and second basis vectors. The resulting map, showing a very regular structure of first sections of Hungarian folksongs, is shown in Figure 7. The point system is built up by large clusters situated along parallel and orthogonal “planes”, which are perpendicular to the plane of the map. Typical section contours are also represented in the cuttings of the “planes”, showing that

1. vertical planes consist of sections beginning at the tonic, fifth and octave,
2. horizontal planes consist of melodies ending at the tonic and fifth,

3. melodies along the lines of intersections of the planes have definite beginning and ending, and their central part varies according to the third co-ordinate in the subspace (Juhász, 2002).

Mapping the first sections of Bulgarian, Sicilian, Appalachian English, French and Slovakian melodies to the subspace described above, the projections show very variegated structures. Applying the typical melody contours in Figure 7 to the clusters of Figure 8, it becomes clear that French, Slovakian and Hungarian point systems are overlapped along a square defined by contours starting or ending at the fifth as well as the tonic. The extensions on the right side and bottom of the “fifth square” show that first sections beginning or ending deeper than the tonic are very usual in French, and less usual in Hungarian and Slovak traditions. On the other hand, the extensions on the left side and the top of the square indicate that first sections beginning or ending higher than the fifth are very rare in French melodies, but very characteristic in Hungarian and Slovak songs. Comparing Bulgarian, Sicilian and Appalachian English point systems to each other, very few common musical forms can be detected, but most of their clusters can be connected to clusters in the above-mentioned 3 systems. Looking at the 6 maps, it is easy to see that a significant part of the clusters has at least one equivalent in other cultures, thus, relatively few clusters represent unique musical features. This recognition supports the legality of the hypothesis concerning the “common language”.

The contour types of the common language having at least 3 corresponding national types are represented in Figure 9, with the Hungarian point system in the background. The most important common contour types, situated in the crossings of the clusters are illustrated by first sections belonging to certain melodies of the six national cultures. The corresponding

whole folksongs are shown in Music Examples 1-5, with Hungarian parallels in both of the first and second sections. Comparing the common contour types to the point system of Hungarian first sections, it is easy to understand, why just the Hungarian system holds the most types of the common language. The points representing the common language are mostly situated inside the “fifth square”, which is very dominant in the Hungarian point system, and also pronounced in Slovak and French clusters (see Figure 8). In the remaining cultures, merely different subsets of the “fifth square” are virulent, but its other parts are represented by sporadic examples. Common types being found below, as well as on the right side of the fifth square fit very well to French melodies. Hungarian, Slovak and Appalachian English pieces of similar contour are more scattered, but they also fill out the corresponding part of the melody space. Common types situated above, as well as on the left side of the “fifth square” are very well represented in Hungarian and Slovak point systems. The largest horizontal cluster of the Sicilian system, constructed by sections ending at the dominant, contains also many common contours. The left side of the overlapped regions of this Sicilian and the corresponding Hungarian and Slovak clusters consist of sections beginning higher than the fifth and ending at the fifth regularly. Such contour types are very usual in Sicilian and Hungarian folksongs, less frequent in Slovakian tradition, and practically unknown in other cultures.

Common types being found above or under the left part of the above-mentioned horizontal cluster are typical in Hungarian and Slovak folksongs, but very rare in another cultures. It follows from the above results that the common language has practically completely been conserved in the Carpathian Basin, and more or less partly in other regions of Europe (and some parts of America, where European musical traditions have been conserved). Figure 9 also shows significant regions of the Hungarian point system over the regions corresponding

to the common language, verifying our earlier statement that the common language takes a significant part of Hungarian music, but other significant parts of this culture have not any European relation. Historical interpretation of the results exceeds the frame of this study, but it is to be remarked that Eastern contacts of Hungarian folk music have already been shown by Kodály (Kodály, 1971).

Further analysis of the clusters can highlight some special forms, too. For example, the very left part of the above-mentioned large horizontal Sicilian cluster corresponds to contours starting higher than the octave and ending at the fifth. Such melodies are not used in any other culture. The bottom part of the Bulgarian “rectangle” shows that first sections ending one tone deeper than the tonic are very frequent in Bulgarian songs, but rare in other cultures.

These examples verify that our mapping system is able to show the relations of different musical systems as spatial regularities of point systems. The contour types determined by self organising maps fit to these structures, and the rather abstract results of self organising mapping are clarified by musical interpretation of the spatial regularities. The structure of the point systems was analysed in a subspace which shows the most articulated structure of Hungarian music, however, it has not been proven that this “paradigm” is optimal for other cultures, too. Although many experiences support the above finding, we cannot consider it to be proven without a systematic and individual study of each of the point systems. However, our main statements are based on the results of self organising mapping, which completely avoids this problem, and the mentioned subspace was used merely to interpret these results.

6. Summary

To describe the oral musical tradition of 6 European nations, we trained self organising maps with section contours derived from representative national folksong collections. The differences of melody numbers and contour type varieties of the collections were compensated by the map sizes. The comparison of the resulting “musical languages” (national contour type collections learned by the maps) showed a significant overlapping. When comparing different cultures, the method can reveal common and special contour types, and it can also characterise some general connections by the common type ratings.

The high ratio of common contour types lead to the supposition of a “common language”, which is essentially a set of contour types being optimal to “understand” the most of the six national types. We have shown that the common types are represented in the Carpathian Basin especially, as a significant but not dominant part of Hungarian, as well as a dominant part of Slovakian tradition.

Independently of self organising mapping, we investigated the point systems representing first sections of the six cultures in a multidimensional “melody space”, too. The two-dimensional projections of the point systems provide a highly visual interpretation of the results of self organising mapping. The musical characteristics of the main clusters are well described in the melody space, therefore these projections clarify the conditions of the different contour types from an overall musical point of view. The simultaneous mapping of the melody sections and the contour types to the “melody space” showed very clear and close musical contacts of national cultures to the common language, thus, a hypothesis of a general archaic musical tradition living in large regions of Europe seems to be worth considering.

The results show a significant interaction between European musical traditions, and a particular completeness of the common musical tradition in the Carpathian Basin. Perhaps, this exceptional melodic completeness played a role in the particular interest taken in this tradition by Bartók and Kodály (Bartók, 1981). Kodály explained the existence of this richness by the fact that this oral tradition also played the part of composed music during long historical periods of Hungary: "*Our folk-music is not that of a crude unlettered class. It is, or has been until very recently, the music of the whole nation.* (p. 28.)" (Kodály, 1925).

Since our general conclusions are based on the study of six European musical cultures, it is easy to see that the study should be extended to further regions of Europe and Asia. We have seen that the efficiency of our method focusing on contour analysis depends on the typical ambit of the studied musical cultures, and it is rather insensible from rhythmical point of view. Thus, the extension of the study to further cultures may require a significant methodological development, too.

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References

Bartók, B. (1981). *The Hungarian Folk Song* by B. Bartók.

Ed: B. Suchoff, Transl: M.D. Calvocoressi, Animations: Z. Kodály.

State University of New York.

Bod, R. (2001a). Memory-Based Models of Melodic Analysis: Challenging the Gestalt Principles. . *Journal of New Music Research* 31 (2002) 27-37.

Bod, R (2001b) *Probabilistic Grammars for Music Proceedings BNAIC 2001*, Amsterdam

Canteloube, Joseph: *Anthologie des Chants Populaires Francais I-IV* (1951) Paris, Durand & C..

Corpus Musicae Popularis Hungaricae I-X. (1951-1997), Budapest.

Csébfalvy K, Havass M, Járdányi P, Vargyas L. (1965). Systematization of Tunes by Computers. *Studia Musicologica VII*. (1965) pp. 253-257

De Poli, G., Prandoni, P. (1996). Sonological Models for Timbre Characterization. In *Proceedings of the First Meeting of the NFWO Research Society of Foundations of Music Research*. Ghent, 13. Sept. 1996.

English Folk Songs from the Appalachians collected by Cecil J. Sharp I-II. (1932) London.

D'Harcourt, Marguirete & Raoul. (1956): *Chansons Folcloriques Francaises au Canada* (1956) Québec – Paris.

Dobszay, L. (1978). Der Begriff Typus in der ungarischen Volksmusikforschung. In *Studia Musicologica XX*. (pp. 227-243). Budapest.

Dobszay, L., Szendrei, J. (1992). *Catalogue of Hungarian Folksong Types*. Budapest.

Favara, Alberto: *Corpus di Musiche Popolari Siciliane I-II*. (1957) Palaermo.

Járdányi, P. (1974). Experiences and Results in Systematizing Hungarian Folksongs. In *Studia Musicologica XXII* (pp. 17-20). Budapest.

Jarvinen, T., Toiviainen, P., & Louhivuori, J. (1999). Classification and categorisation of musical styles with statistical analysis and self-organising maps. Manuscript.

Juhász, Z. (2002). The Structure of an Oral Tradition – Mapping of Hungarian Folk Music to a Metric Space. *Journal of New Music Research* 31 (2002) No 1, (pp 295-310).

Juhász, Z. (2004). Segmentation of Hungarian Folk Songs Using an Entropy-Based Learning System. *Journal of New Music Research* 33 (2004) No 1, (pp 5-15).

Kodály, Z (1925): New Music from Old. *Modern Music. A Quarterly Review. November–December 1925. Vol. III. Number 1. pp. 25–29.*

Kodály, Z. (1971). *Folk Music of Hungary*. Budapest, Corvina.

Kohonen, T (1995) *Self-organising Maps*. Berlin:Springer-Verlag

Krumhansl, C.L., Louhivouri, Y., Toiviainen, P., Jarvinen, T., Eerola, T, (1999): Melodic Expectation in Finnish Spiritual Hymns: Convergence of Statistical, Behaviora, and Computational Approaches. *Music Perception 1999, Vol. 17, No.2, 151-195*.

Krumhansl, C.L., Toivanen, P., Eerola, T, Toiviainen, P., Jarvinen, T., Louhivouri, Y.(2000): Cross-cultural music cognition: cognitive methodology applied to North Sami yoiks. *Cognition 76 (2000) 13-58*.

Leman, M (200): An Auditory Model of the Role of Short-Term Memory in Probe-Tone Ratings. *Music Perception 17 (4), pp 481-509 (2000)* .

Rhodes W. (1965) The Use of Computer in the Classification of Folk Tunes. *Studia Musicologica VII. (1965)*. pp. 339-343.

Sachira, D., Milan, R. (1997). Dynamic Programming Approach to Time Normalized Similarity Evaluation of Melodical Structures. In *Proc. of Meeting of the Study Group on Computer Aided Research in Musicology, Dolná Krupá, 1997*.

Sandell, G.J. & Martens, W.L. (1995). Perceptual Evaluation of principal component based synthesis of musical timbre. *In Proc. of Meeting of the Study Group on Computer Aided Research in Musicology, Dolná Krupá, 1997.*

Slovenské L'udové Piesne, (1950) Bratislava.

Stoin, Vassil: Chants Populaires de la Partie Centrale de la Bulgarie du Nord. (1931) Sophia.

Szendrei, J. (1978). Auf dem wege zu einer neuen Stilordnung der ungarischen Volksmusik. *In Studia Musicologica XX.* (pp. 361-379.) Budapest.

Toiviainen, P. (1996). Optimizing auditory images and distance metrics for self-organizing timbre maps. *Journal of New Music Research, 25,* 1-30.

Toiviainen, P (2000). Symbolic AI Versus Connectionism in Music Research. *In E. Mirinda (Ed.), Readings in Music and Artificial Intelligence.* Amsterdam: Harwood Academic Publishers (2000).

Toiviainen, P., Eerola, T (2001): A Method for Comparative Analysis of Folk Music Based on Musical Feature Extraction and Neural Networks. In: VII International Symposium on Systematic and Comparative Musicology III International Conference on Cognitive Musicology 2001 Jyvaskyla, Finland / Conference Program, Proceedings & List of Participants pp. 41-45.

Figure captions

Figure 1. Construction of the melody vector \underline{x} from the music. The sampling of the pitch-time function is represented by dots on the thick curve. Pitch values increase 1 by one semitone, zero level corresponding to the C tone.

Figure 2. The self organising map estimating the melody contour types $\underline{c}_{i,j}$ and the weight matrices $\underline{S}_{i,j}$ at locations (i, j) from the collection of melody vectors \underline{x} .

Figure 3. Classification distributions of 12*12 self organising maps, trained with first sections of the six national cultures. Diagram *a* shows that five of the six curves are in the interval of $0.8 \leq f(2) \leq 0.9$ for $N \leq 2$. Hungarian distribution, represented by the thick line, verifies that less than 70% of Hungarian melodies were successfully classified in the given conditions. Diagram *b* represents the same curves, with the exception that the Hungarian distribution arises from a 16*16 map.

Figure 4.

a. Ratings of first section types being activated by types of different national cultures. The sequence of the columns in a group corresponds to that of indicated in the horizontal axis. For example, the columns in the group indicated by “FR”, show the ratio of French types activated by Hungarian, Slovak, French, Sicilian, Bulgarian and Appalachian English types.

b. Ratings of first section types activating types of different national cultures. The sequence of the columns in a group corresponds to that of indicated in the horizontal axis. For example,

the columns in the group indicated by “FR”, show the ratio of Hungarian, Slovak, French, Sicilian, Bulgarian and Appalachian English types, activated by French ones.

c. Averages of the groups in Figure 4b (left) as well as Figure 4a (right).

Figure 5.

a. Rates of national types activating the common language. The four columns correspond to first, second, last but one and last sections.

b. Rates of the types of the common language activated by national types, for the four sections.

c. Averages of the groups in Figure 5a (left) as well as 5b (right).

Figure 6. Co-ordinate sequences of the central point and the four basis vectors of the subspace derived from the spatial structure of first sections of Hungarian folksongs. First, second and third basis vectors stand for the mean pitch level at the beginning, ending and central parts of the sections, respectively.

Figure 7. Melody map (two dimensional projection of the multidimensional point system) of the first sections of 2323 Hungarian folksongs. Possible melody contours in the cuttings of the vertical and horizontal clusters are also represented.

Figure 8.

a. Melody maps of first sections of the six national cultures. The projecting plane is the same as in Figure 7. Points being situated closer than a critical limit in the multidimensional melody space are connected with lines.

b. Self organising maps of the common language excited by different national types. The columns show the number of national types having been classified as close relatives of the common type assigned to the given location of the map. The maps show that different musical cultures excite different areas of the common language.

Figure 9. Melody map of the contour types of the first sections of the common language (triangles), with Hungarian first sections in the background (empty circles). The concrete musical examples, illustrating the most important contour types of the common language, are first sections of the melodies shown in Music Examples 1-5.

Music examples

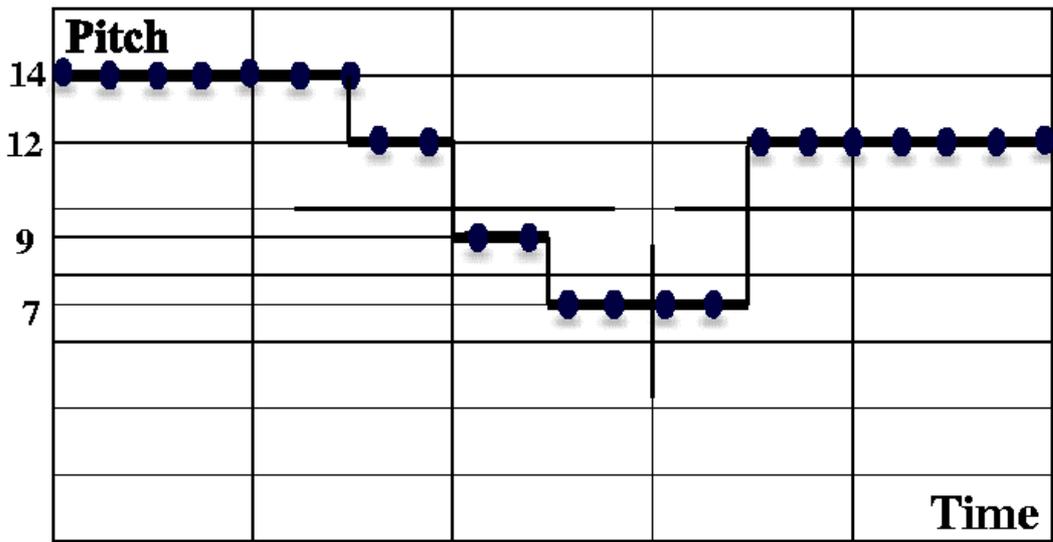
Music Example 1. Examples of contacts between Slovak and Hungarian folksongs. The four sections are separated by bar lines. Melodic relations have been searched for first and second sections systematically. However, third and last sections of example 1, as well as last ones of example 3 are also close relatives.

Music Example 2. Examples of contacts between French and Hungarian folksongs. The four sections are separated by bar lines. Melodic relations have been searched for first and second sections systematically. The relation of the remaining parts of example 1, as well as the last sections of example 3 is also perceptible.

Music Example 3. Examples of contacts between Sicilian and Hungarian folksongs. The four sections are separated by bar lines. Melodic relations have been searched for first and second sections systematically. First and third Sicilian examples are of two section structure.

Music Example 4. Examples of contacts between Bulgarian and Hungarian folksongs. The four sections are separated by bar lines. Melodic relations have been looked for first and second sections systematically. The relation of the whole melodies in examples 2 and 3 is rather clear.

Music Example 5. Examples of contacts between Appalachian English and Hungarian folksongs. The four sections are separated by bar lines. Melodic relations have been looked for first and second sections systematically.



$\underline{x} = [14 \quad \dots \quad 14, 12, 12, 9, 9, 7 \quad \dots \quad 7, 12 \quad \dots \quad 12]$

Figure 1.

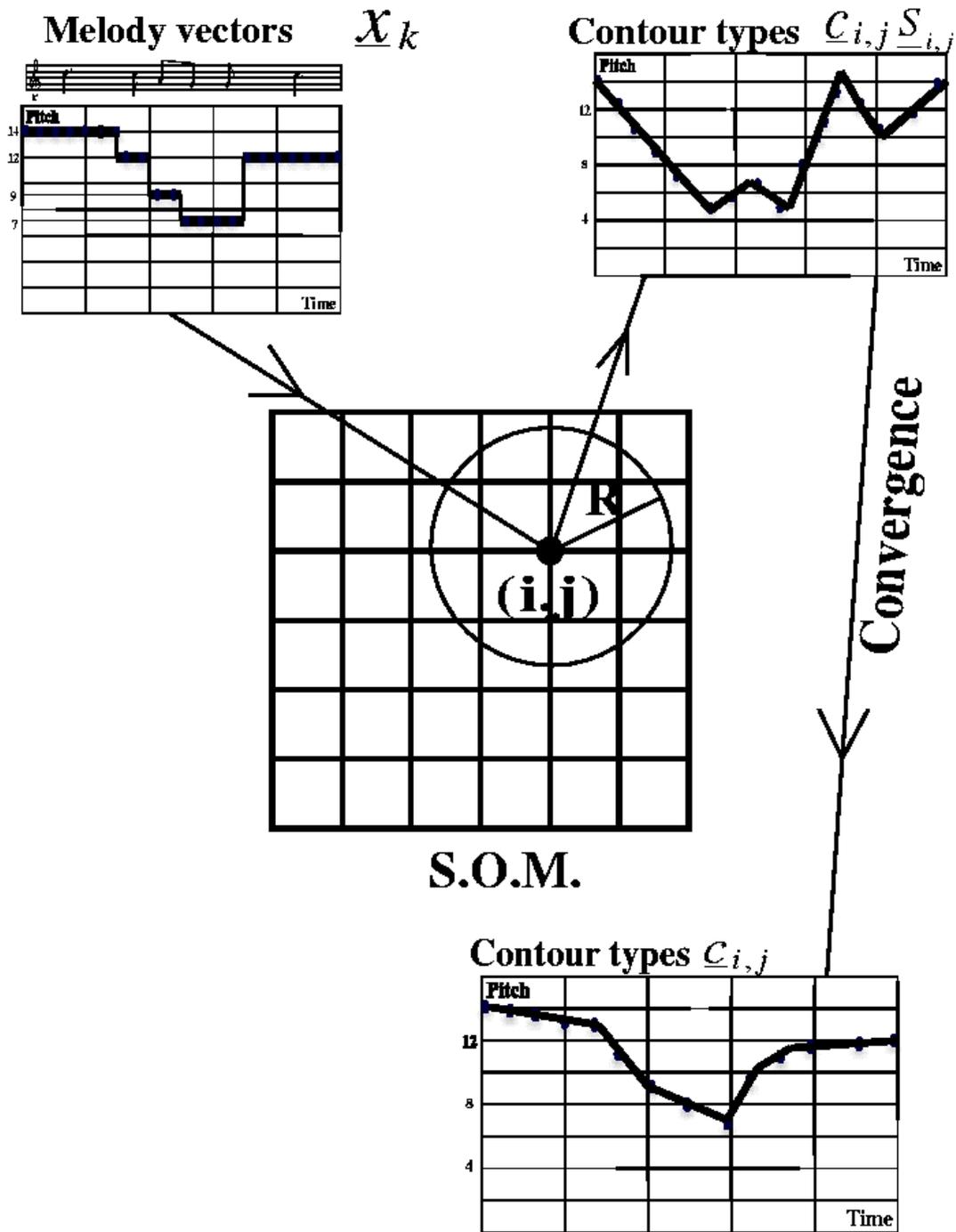
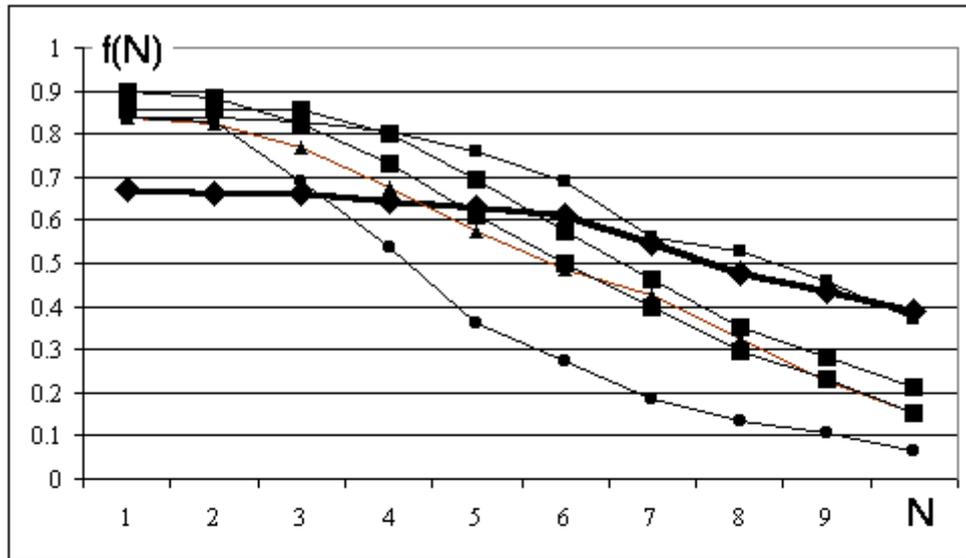
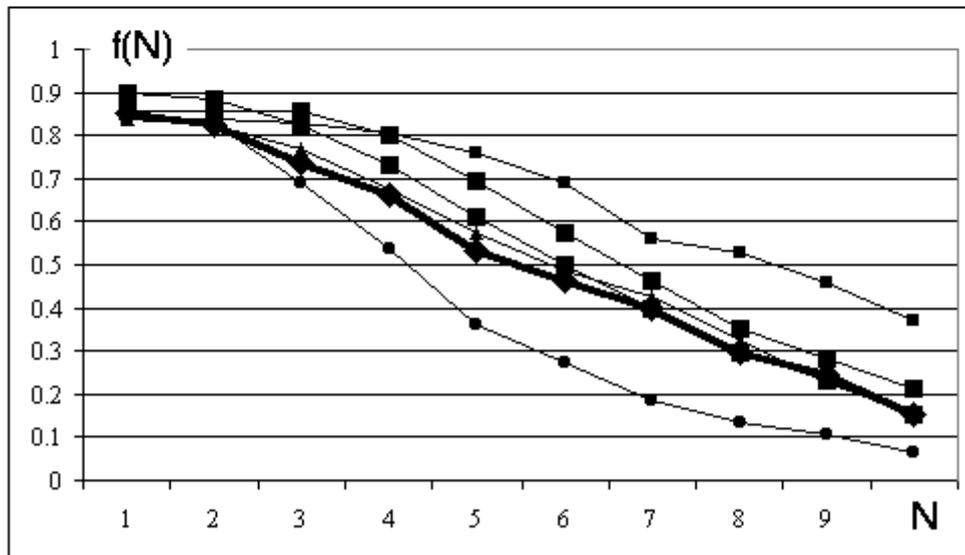


Figure 2.

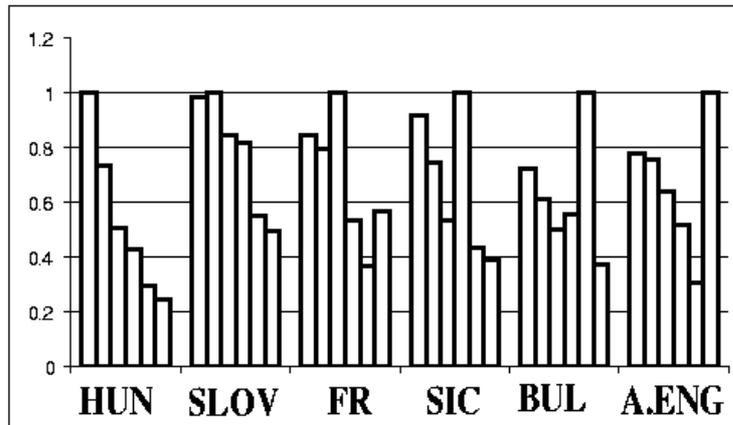


a

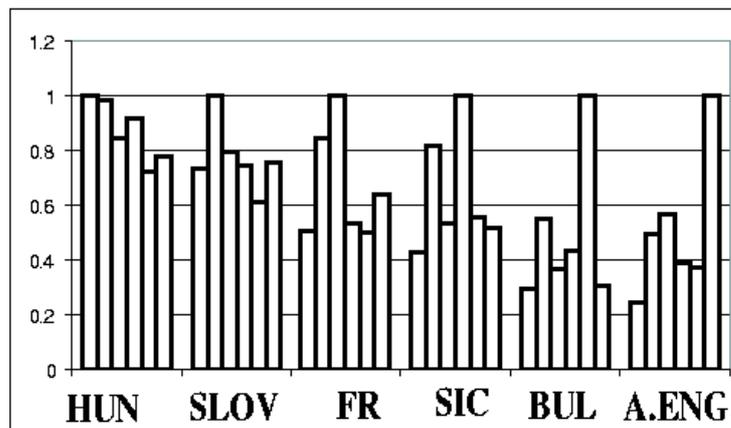


b

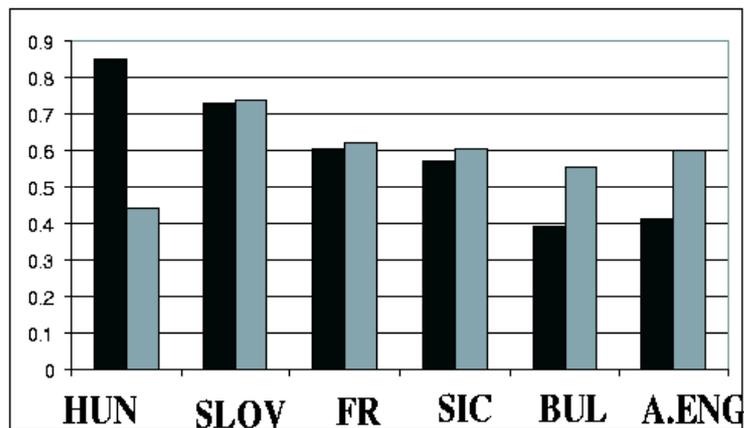
Figure 3.



a

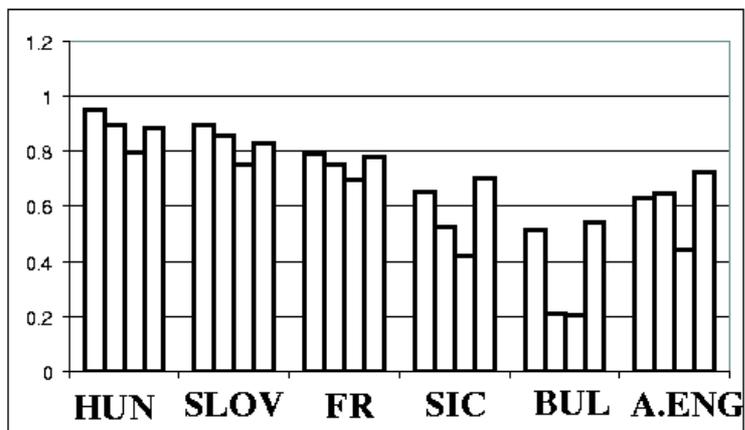


b

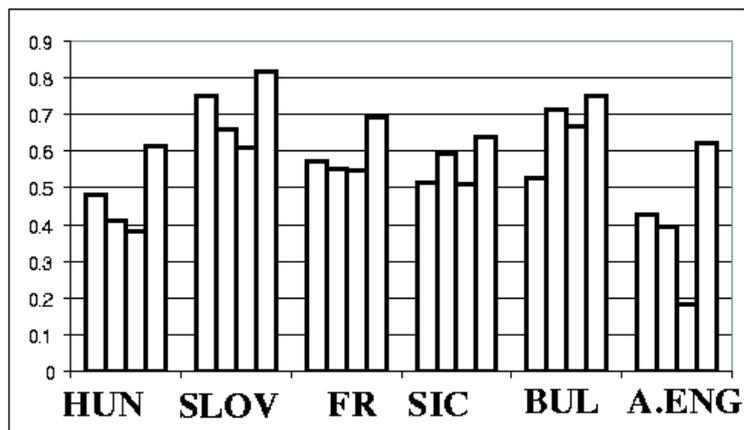


c

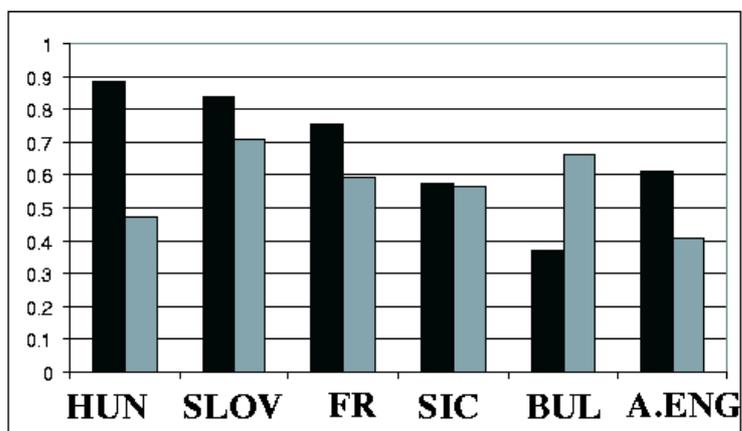
Figure 4.



a



b



c

Figure 5.

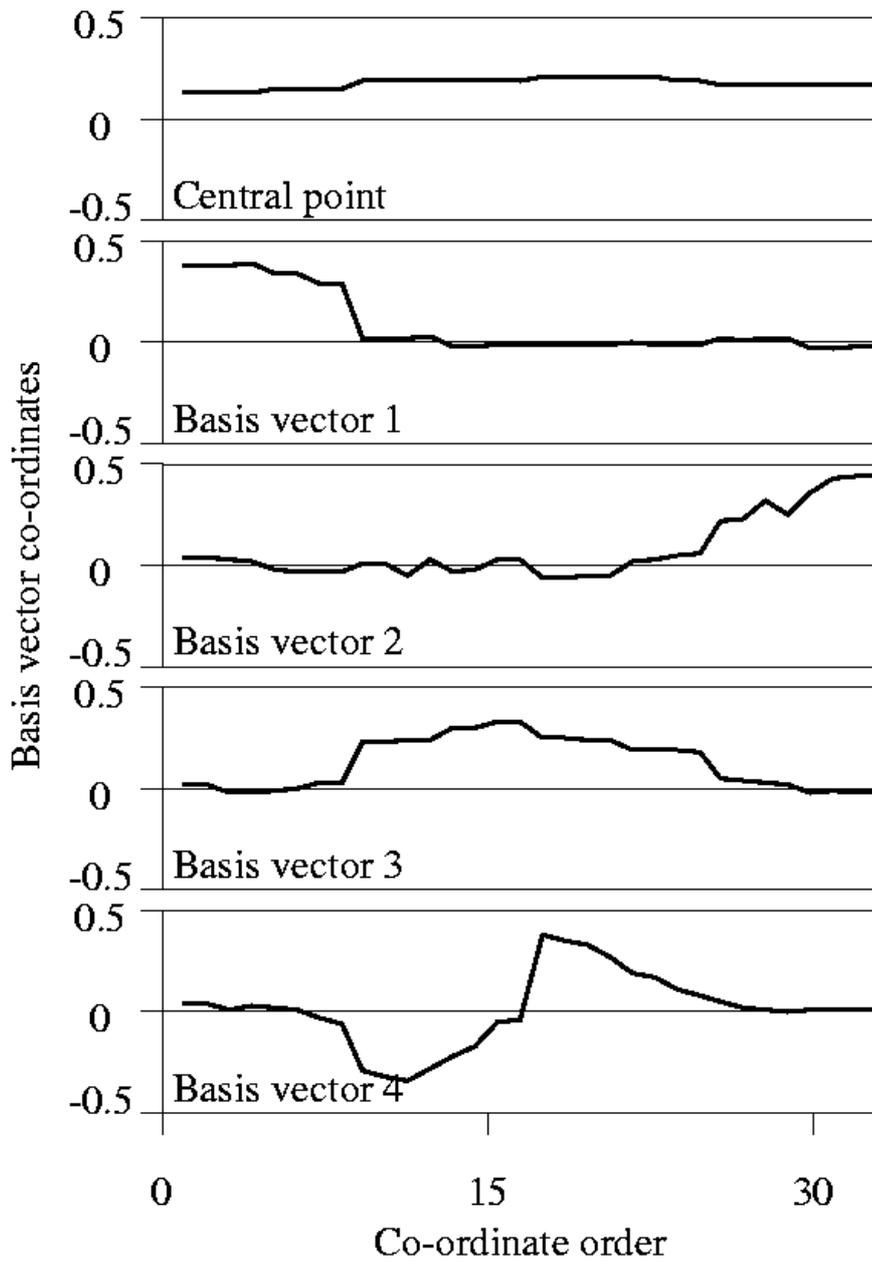


Figure 6.

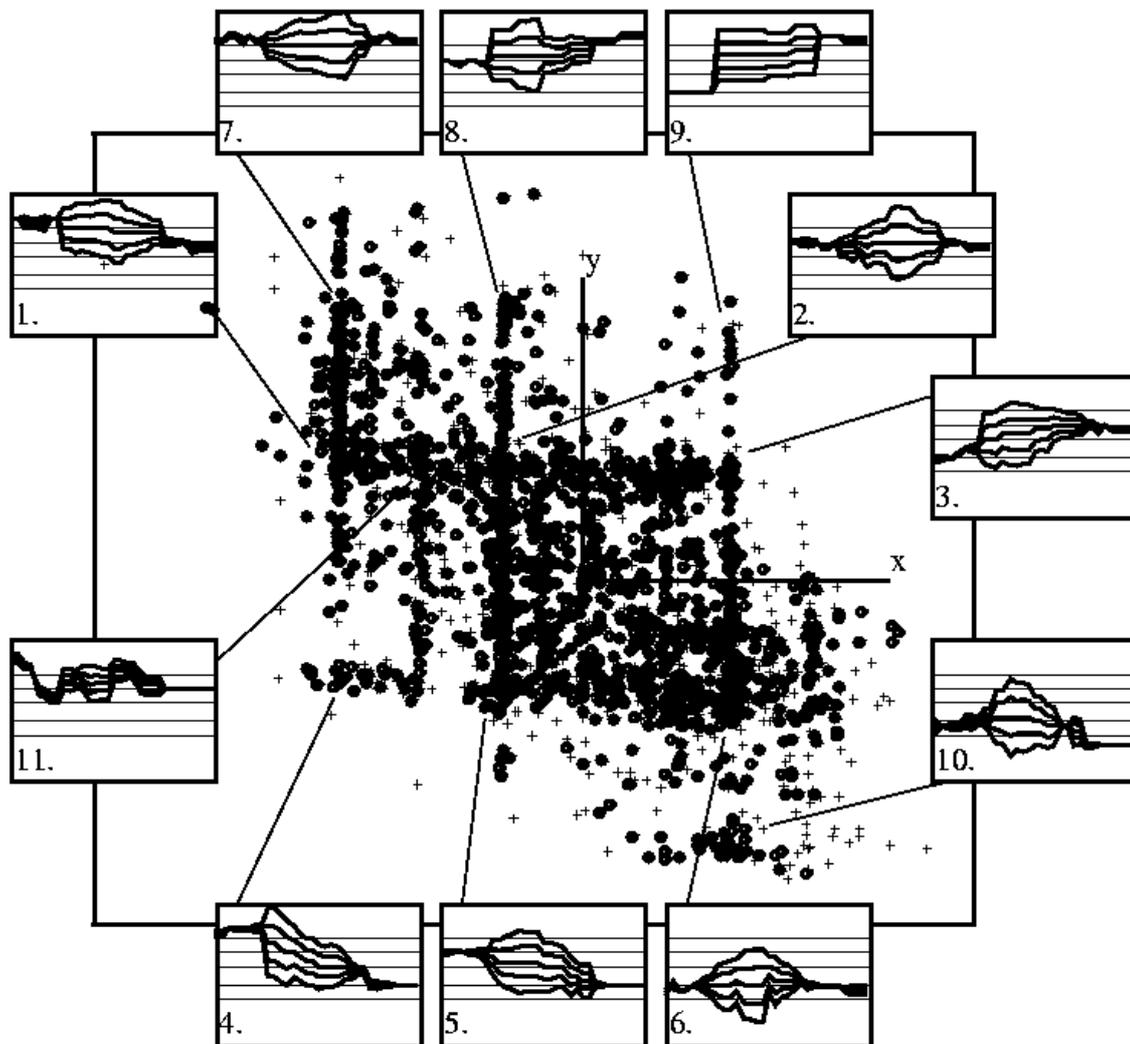
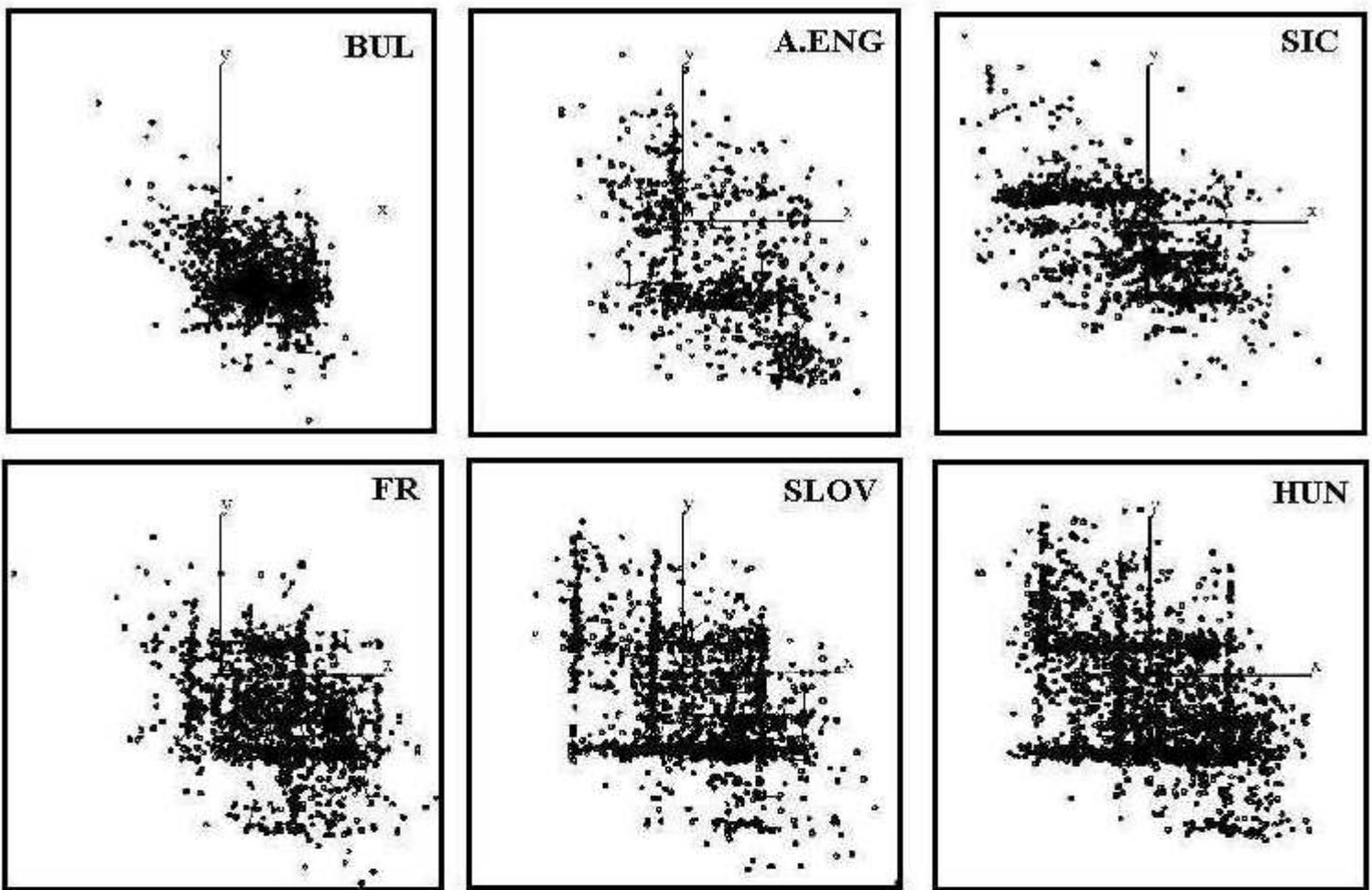
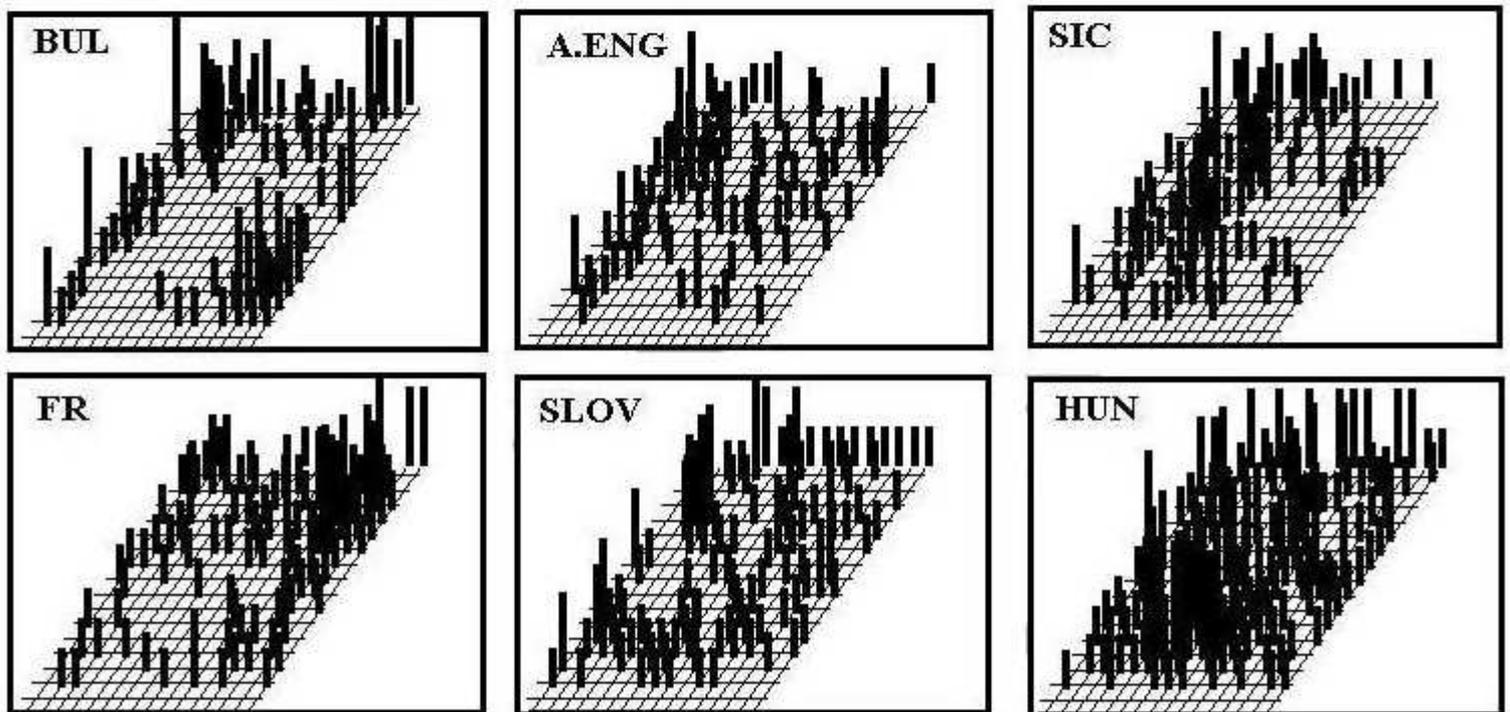


Figure 7.



Melody space projections



Self organising maps of the common language excited by national contour types

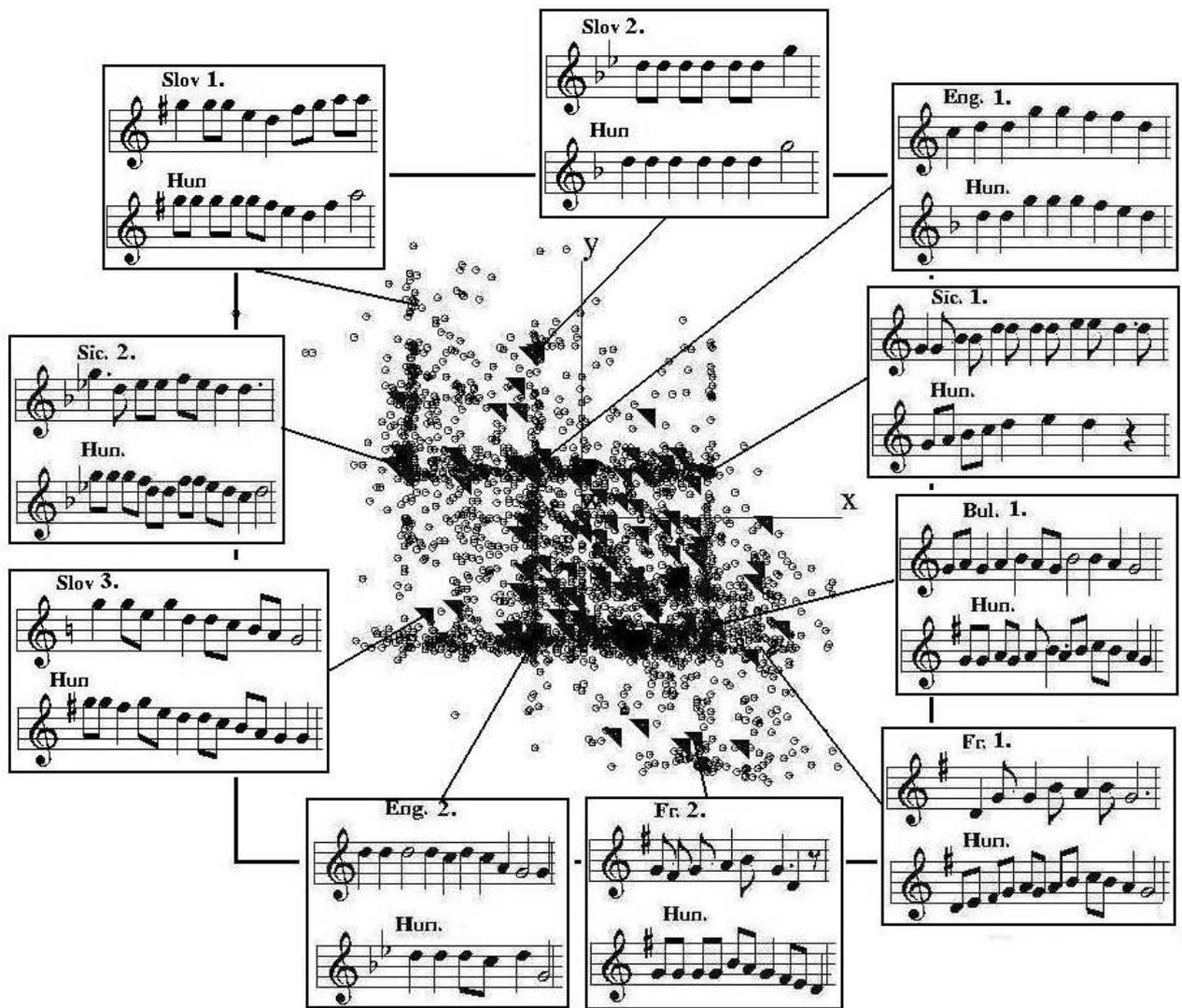


Figure 9.

Slovak-Hungarian contacts

Slov 1.



Hun



Slov 2.



Hun



Slov 3.



Hun



The image displays three pairs of musical staves, each pair representing a comparison between a Slovak (Slov) and a Hungarian (Hun) melody. Each pair is labeled at the top. The first pair, 'Slov 1.', is in G major and shows a Slovak melody with eighth-note patterns and a Hungarian version with a more rhythmic eighth-note pattern. The second pair, 'Slov 2.', is in F major and shows a Slovak melody with eighth-note patterns and a Hungarian version with a more rhythmic eighth-note pattern. The third pair, 'Slov 3.', is in G major and shows a Slovak melody with eighth-note patterns and a Hungarian version with a more rhythmic eighth-note pattern.

Music example 1.

French-Hungarian contacts

Fr. 1.



Hun.



Fr. 2.



Hun.



Fr. 3.



Hun.



Fr. 4.



Hun.



Music example 2.

Sicilian-Hungarian contacts

Sic. 1.



Hun.



Sic. 2.



Hun.



Sic. 3.



Hun.



Music example 3.

Bulgarian-Hungarian contacts

Bul. 1.



Hun.



Bul. 2.



Hun.



Bul. 3.



Hun.



Music example 4.

A. English-Hungarian Contacts

Eng. 1.



Hun.



Eng. 2.



Hun.



Eng. 3.



Hun.



Eng. 4.



Hun.



Music example 5.