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TOMUS VII

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1965

Systematization of Tunes by Computers

by

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Budapest

The Folk Music Research Group of the Hungarian Academy of Sciences has begun work on the European Catalogue, *i.e.* the musically systematized collection of the folk music of European nations for comparative purposes. Owing to the quantity and variety of the material gathered in the first year, it has become clear that either our progress in the analysis and systematization of the material is going to be very slow, or we have to choose a faster and more efficient method. For this reason we have introduced experiments using information processing methods into our work.

As soon as we had been informed by mathematicians with musical knowledge about the possibilities, the first basic principle was formed: *complete tunes* must be introduced into the memory of the electronic brain, instead of the detailed *characteristics* of the songs. This has two advantages: 1. The complete melody is always more than characteristics in any quantity: 2. The characteristics are always stated according to the interest and purposes of a certain period. But if we introduce the complete melody into the memory, we can always get information about it, as problems arise later.

The next problem is how to introduce the tune into the computer. In principle, coding is a perfect solution; in practice it is slow and expensive. The more completely we want to introduce the melody, the more complicated the process including revision and input. This difficulty must be overcome by the method advised by the mathematicians: the songs are not imputed by coding, but are immediately read in without coding.

In this case the question of pitch-level is easily solved by the use of a specialized instrument provided with keys, as various keys induce different signs. We had a musical problem with the rhythm. We had to reckon with different tempos and several individual inexactitudes in playing.

In order to avoid this factor, our mathematician-collaborators have suggested such a program, by which, admitting a certain error score, we can introduce the desired rhythm into the computers. This process has been improved by several experiments: different rhythms were played by different persons (with a Morse key so far) and the final programs were worked up on that basis. The solution of further tune determining factors, *e.g.* limits of bars, phrases, lines, etc. do not cause any difficulty.

The problem of the instrument capable of carrying out the operation had to be solved separately. We have employed the electric accordion of K. Cser which was constructed for this very purpose. The ambitus was restricted to three octaves (one under the last tone and two over it). This is enough as we have to deal with song-melodies; but we have found it important for the tune to be heard when the key is pressed, for the sake of control.

With this method we could ensure the relatively fast introduction of a great number of tunes into the computer; so the primary condition of a vast catalogue was given. Tests for further possibilities of accelerating the process are being made: to eliminate the music-instrument and to introduce the material into the computer directly from a tape. Thus the mistakes can be corrected previously on the tape and not in the computer; the player's presence is not needed as he can do the work at his working place; no staff is needed; the work can be done in the night; finally, reading in, accelerated by an octave, is possible.

The following characteristics of the tune can be introduced with our present method: the pitch of the tune in a value relative to the last tone, expressed in the twelve-tone system, rhythm values down to 1/32, triplet and quintuplet values (in case of need its absolute length as well), bar- line- and melody limit, corona sign and melisma. By the present method stress, deviation from the twelve-tone system, the timbre and the small oscillations of the rhythm in the rubato-style are not registered. They are omitted so far from the mechanical comparison and systematization; if these prove to be important, they will have to be studied separately.

The further problem is only what we want to learn about the songs. Every question concerning the easily specifiable properties in the tunes (melody-line, tonality, etc.) the choosing of songs, occurrence of tune connections and other more hidden regularities, as well, are easy tasks.

More complicated problems than these can be solved: mechanical determination of the characteristic properties of the songs, their classification by characteristics, determination of the variant-character according to the degree of relationship and so on. And as the complete material with all its properties is at our disposal in the memory of the computer, the solving of any other musically or mathematically determinable task seems possible.

* * *

In analysing the rhythms and melodies of a great number of folk tunes we made use of the advantages offered by high speed electronic computers. We tried to employ the computer, because our problem consisted of processing information distributed throughout the melody, a problem very similar to others regularly dealt with by electronic computers.

Their use requires precise and unambiguous statements of all the data and all the criteria of classification, as well as the setting up of mathematical algorithms for the computation. This increased accuracy, of course, entails increased requirements in the first stage of the work. Every possibility must be accounted for, because the computer can perform only exactly defined tasks explicitly stated in the program. However, this increased accuracy means not only additional effort, but at the same time may lead to additional scientific results, valuable even without the application of the computer.

The classification and analysis of folk tunes presupposes their notation in a unique and unambiguous way, not varying with the personality of the performer. These problems are, of course, far from new, but the use of the mathematical tool raises them again in a very pronounced way. The resulting additional effort is, therefore, far from being wasted, because these questions need clarification even without the requirements raised by these methods.

After we had found a workable solution to the above questions we had to store the melodies already unambiguously defined in the memory of the computer.

The first and obvious possibility was to use the traditional way, and to punch the rhythms and melodies by way of a code system into punched tapes or cards. This method, however, is not to be recommended, partly because of some considerations derived from information theory, and partly because of the great amount of labour required by this method. As to the first consideration, the information theory states that the errors committed in the course of the coding and input processes would result in so-called "noises" which would result in inaccuracies during further analysis. The "noise" factor could only be eliminated at a later stage by the use of a high frequency generator ("audio-control"). This device reproduces the melodies stored in the memory, and the faults can be detected simply by listening. Such experiments proved successful, but the procedure is rather uneconomical.

The other method is based on a characteristic of the synchron computers, namely that the duration of an impulse may be measured with great accuracy within a given interval. By employing a bistabile multivibrator system, one channel to each given pitch level, the impulses of different length, originated in any channel can be registered unambiguously. (This can be realized by means of the number generator and accumulator of the computer, and by instructions connecting the above units and by counting the number of identical operations performed.) The various multivibrators can be actuated through resonators, at least in principle. In this case the input of melodies can be carried out through a microphone by means of a well-defined instrument. As, however, such an input requires the solution of a number of technical problems, we actuated the multivibrators by means of an electric connection coupled with the keys of the keyboard of a musical instrument. In this way it was possible to play the melodies, to store them in the memory of the computer, and to check them simultaneously and listen to them.

In our experiment we used a keyboard with three octaves. The sounds and chords were read into the computer in the above mentioned way, and translated into machine language by an appropriate program stored in the computer.

The method also makes it possible to switch over from absolute periods to relative ones by means of a suitable program. The absolute periods express the inexactitude of the rhythm and the fluctuation of the tempo with which the melodies are played on the keyboard. The bar-lines and measures necessary to the transformation can be put in either by means of special keys of the keyboard, i.e. simultaneously with the playing of the melodies, or by means of a punched tape. The normalization by bars and the correction within the bars can be assured by the appropriate selection of these bar-lines and measures. It is apparent that even in case of the most rigorous keeping of the bar, any rhythm unit will differ both from all other actual and from the theoretically computed rhythm units.

So, for instance, if the theoretically computed length of a $\frac{1}{4}$ sound is denoted by x_o^4 (which, of course, depends on the bar type, as, for instance, we have in the case of a three-in-a-measure bar $x_o^4 = \frac{1}{3}$ and in the case of a four-in-a-measure bar $x_o^4 = \frac{1}{4}$) then we have for each input quarter

$$E_{10}^4 = (x_i^4 - x_o^4) \qquad (i = 1, 2, \ldots, n)^1$$

further

$$E_{ik}^4 = (x_i^4 - x_k^4)$$

where

$E_{ik}^4 \leqq 0$ (i, k = 1, 2, ..., n; if n stands for the number of the input quarters).

It is necessary to establish for what value of the threshold number E^4 x_i can be considered as a quarter if $(x_i^4 - x_o^4) \leq E^4$ $(i = 1, 2, \ldots, n)$.

The number E^j may be determined by two different methods: 1. The E^j values may be determined *a priori*, on the basis of some general experience and knowing the theoretical values of the different rhythm units. That means, we can give an interval $I^j \ni x_o^j$ (not necessarily symmetrical) in an *a priori* way, for which x_i may be regarded as an x_o^j rhythm unit, if $x_i \in I^j$. 2. The values of E^j can be determined by the computer itself in an *a posteriori* way, i.e. after a suitable learning period. In this case each performer must play for a certain period. After playing some standard melodies we obtain the characteristic limits of error. By doing so we make use of the fact that the actual length of the rhythm unit is a probability variable, the distribution of which is characteristic for each individual, and we can carry out the corresponding statistical analysis. Our experiments support the view that even the simpler method (1) provided the required degree of accuracy.

[1] The exponent 4 (in the general case j) indicates that these $E^4{}_{ij}$ values (in general $E^j{}_{ik}$) are the errors belonging to the quarter sounds (in general to the $\frac{1}{j}$-th).