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Computer measurements of the tone scale in performed music by means of frequency histograms

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III. MUSICAL ACOUSTICS

A. COMPUTER MEASUREMENTS OF THE TONE SCALE IN PERFORMED MUSIC BY MEANS OF FREQUENCY HISTOGRAMS(1)

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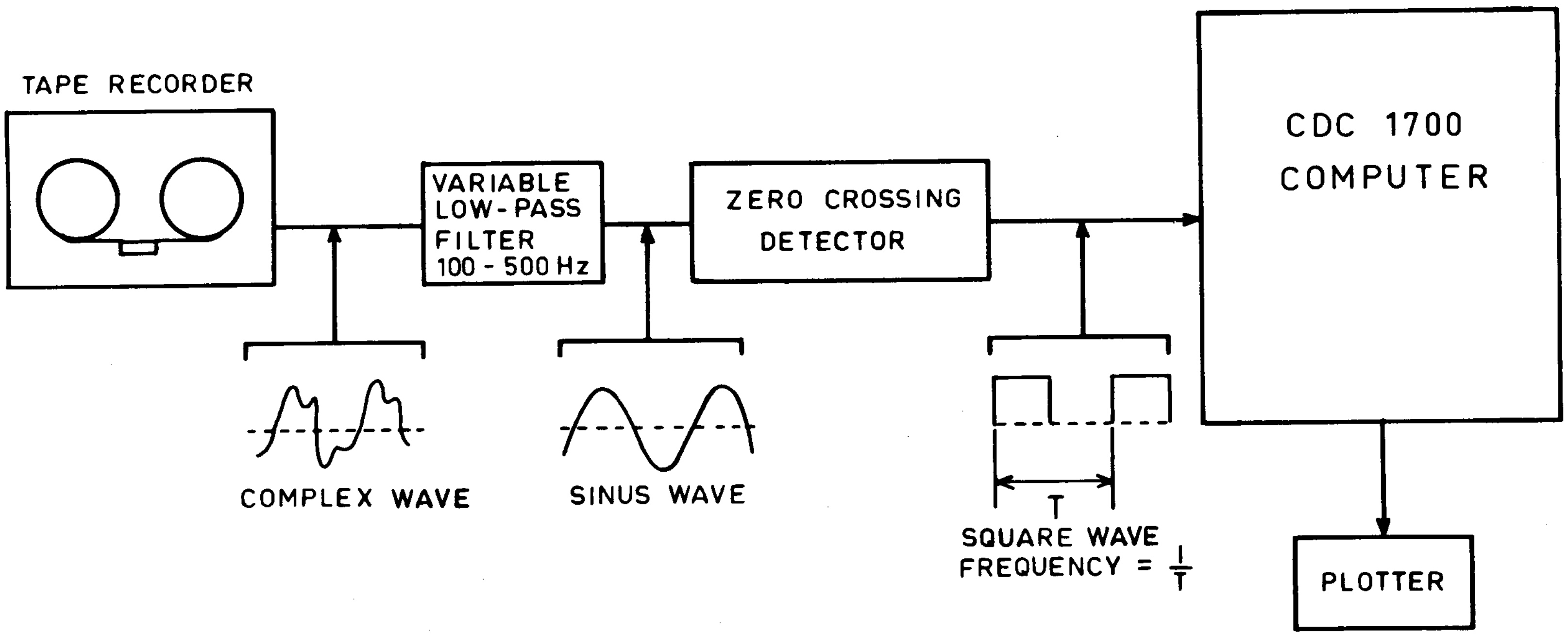
Essential properties of a performed melody are determined by the produced tonal scale, i.e., the set of fundamental frequency mean values. These mean values are difficult to determine by ear, and it means a hard work obtaining them even from a graphical analysis of the fundamental frequencies as a function of the time. This paper records some results on measurements on the frequency distribution in melodies played on instruments. Using a computer these results are obtained in real time in the form of histograms. Such histograms contain information on the underlying tonal scale, and can be used to characterize the melody performed.

Equipment

The fundamental frequency analysis was carried out with the conventional set up of a variable LP-filter for isolating the fundamental, and a zero-crossing detector, Fig. III-A-1. The output of the detector is a square wave that is fed into the computer. The internal clock of the computer is used as the frequency standard. The period lengths are converted to frequency values. These frequency observations are used for a continuous build up of a fundamental frequency histogram. The measured frequency values are ordered in different classes. In the measurement presented here, the class width was chosen to be 1 Hz. The classes grow as a function of the occurrence of the corresponding fundamentals in the melody. The frequency class values are stored in the computer memory. As a second step in the data processing, the probabilities of the different classes are computed, i.e. the total area under the histogram envelope is normalized. The measurement of the period length and the continuous build up of the frequency histogram is made in real time. The histogram is displayed on a data scope, and a hard copy could be obtained by means of an x-y plotter.

The results obtained with the described method are rather unsensitive to disturbances in the tape recordings. Noise and flutter expand the histogram peak widths, and a systematical error in the playback speed of the



EQUIPMENT FOR ON-LINE CALCULATION OF PROBABILITY DISTRIBUTION OF FUNDAMENTAL FREQUENCY

Fig. III-A-1. Block diagram of the equipment used.

tape recorder appears as a relative change in the frequency scale, that however does not affect the sizes of the musical intervals.

Measurements

Fig. III-A-2 shows a histogram of a tone scale, blown on a flute, and analyzed with the described method. The mean values of the fundamentals constituting the tone scale are approximately given by the modes. In the histograms, the modes appear as the peak maxima. The broadness of the peaks gives a measure of the stability of the tones blown. The area of the peaks corresponds to the percentual occurrence of the fundamentals in the analyzed tone scale. The modes of the fundamentals, their percentual occurrence in the melody, and their stability, obviously correspond to certain interesting properties of the melody, as will be shown below.

The set of fundamental frequency modes produced by two different players playing the same melody is shown in Table III-A-1. The instrument was a "spilåpipa", a Swedish folk instrument of recorder type [2]. In the Table the fundamental frequencies and the interval sizes they form with the do-frequency are listed. The largest difference between the scales of the two players is observed on the third, that is blown higher by player A. This agrees well with the statement of Kjellström, that player A plays his melodies in a major-like tonality, whereas player B keeps to a more minor-like tonality [3]. This difference in the size of the third can be explained by the acoustical properties of the flutes [4].

TABLE III-A-1

Fundamental frequency modes in a melody played by two players

Player A			Player B		
Scale tone	f Hz	Interval rel. f_{do} cents	Scale tones	f Hz	Interval rel. f_{do} cents
sol :	460	-497	sol :	475	-498
si :	565	-141	si :	589	-136
do :	613	0	do :	637	0
re :	680	+180	re :	705	+175
mi :	749	+347	mi :	764	+314
fa :	810	+482	fa :	840	+478
sol :	905	+674	sol :	929	+653

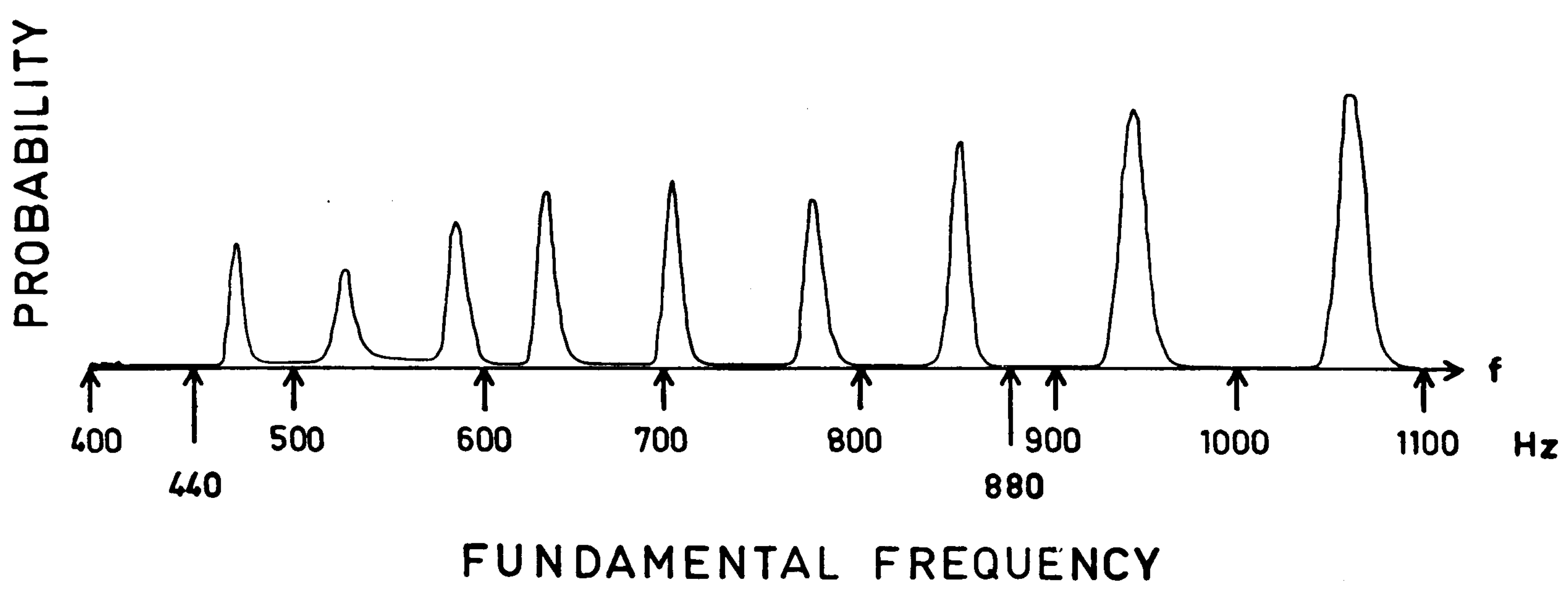


Fig. III-A-2. Histogram of a tone scale blown on a flute.

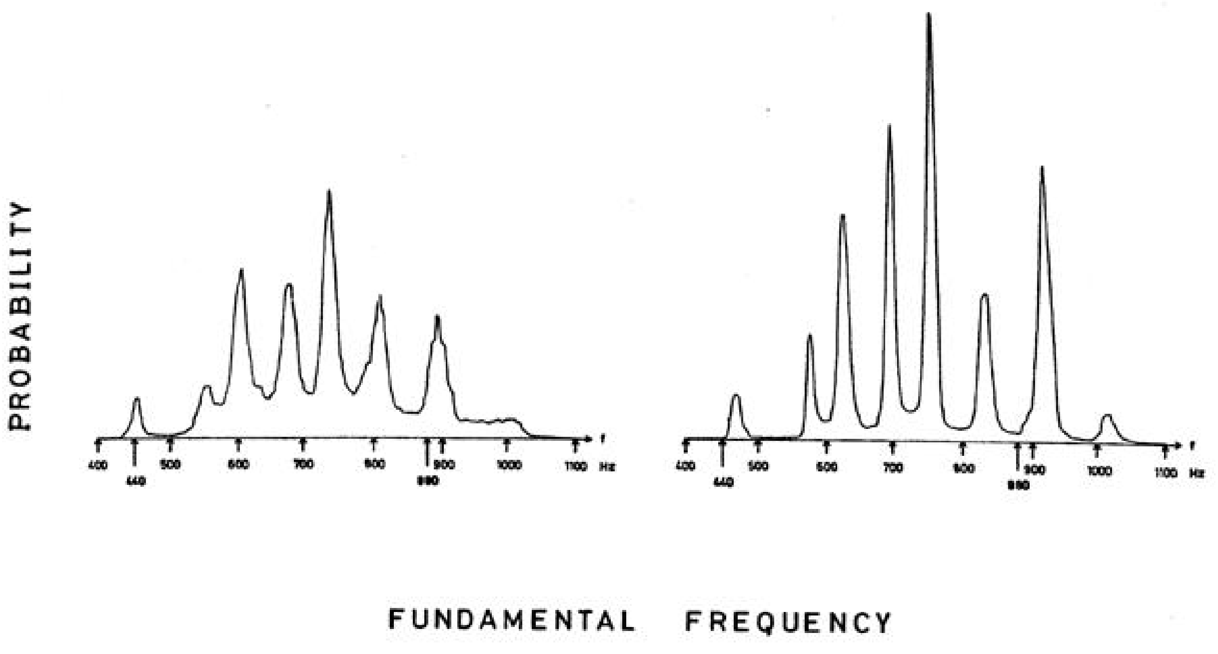


Fig. III-A-3. Histograms of the same melody played by two players; left: player A, right: player B.

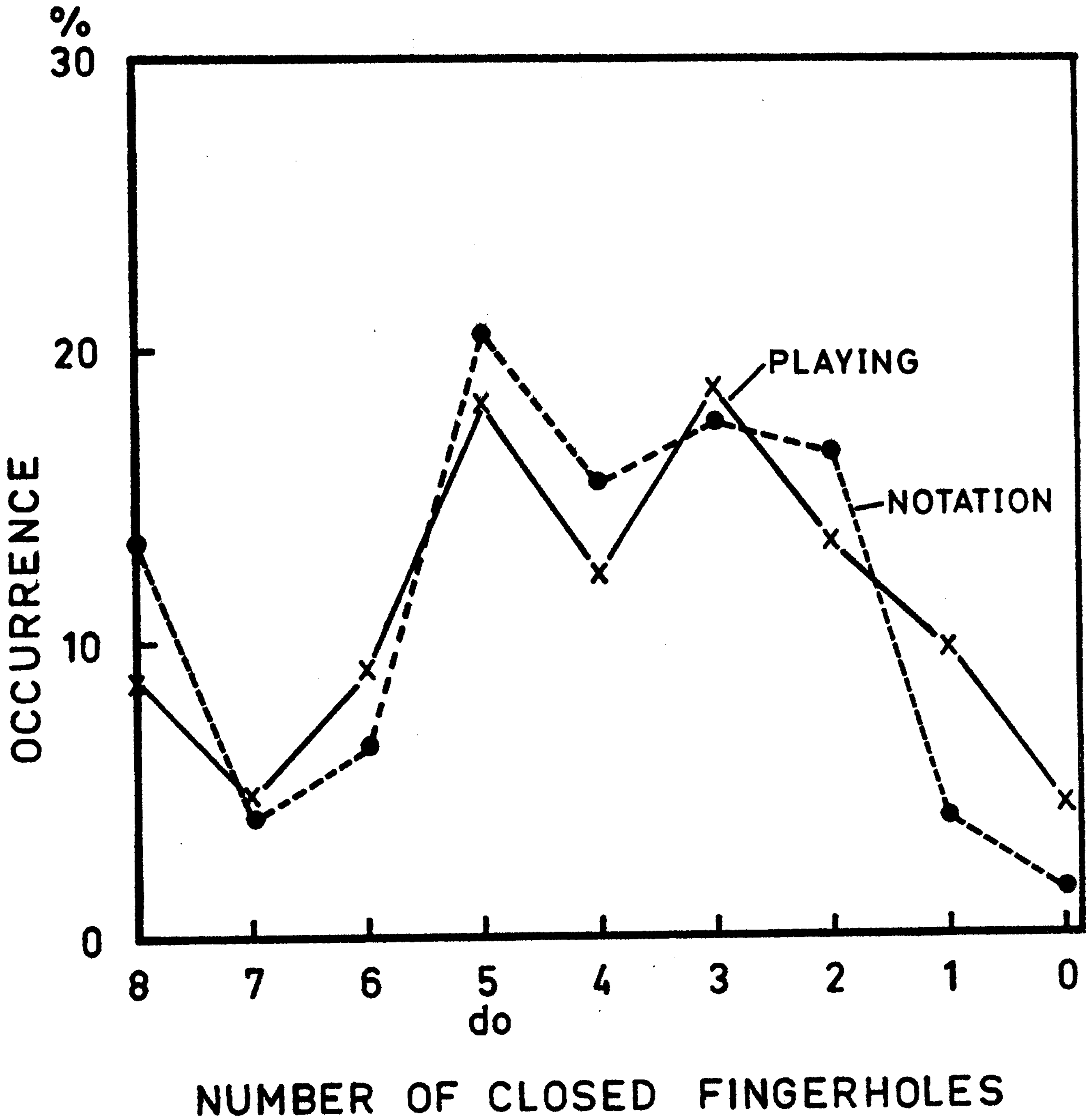


Fig. III-A-4. Percental occurrence of the different fundamentals in a melody according to an analysis of the notation (dashed line) and of the performance (solid line).

Considerable differences between the two players were observed also in the fundamental frequency stability in playing the same melody. This is illustrated in Fig. III-A-3, showing histograms of their versions of the same melody. The greater spread of player A corresponds well with the observation by Kjellström, that this player uses a big amount of ornaments and glissandoeffects in playing (5). Thus, the method gives also some information concerning the personal style of playing.

According to Ling, the percentual occurrence of the different tones in the notation of a melody is a characteristic that may be employed as a classification aid (6). The computer method described above obviously allows an automatical analysis of this characteristic. This is evident from Fig. III-A-4, giving the result of a statistical investigation of the notation of the type suggested by Ling, and the corresponding analysis of the playing obtained from the computer. The differences between the results of the two different methods are smaller than could be expected in view of the well known discrepancies between the notation and the acoustical realization of a melody. The graph thus suggests the possibility of automatical extraction of an important characteristic of a melody.

Acknowledgments

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References

(1) This is a condensed version of a paper given at the symposium of the International Folk Music Council in Stockholm, June 1969. An unshortened version will be printed in the proceedings of this symposium.

(2) This instrument is presented in detail in Kjellström, B.: "Spelpipan i Dalarna", stencil, Music Museum, Stockholm 1964. See also Moeck, H.A.: Journal of the Swedish Society of Musicology 36 (1954), pp. 55-83.

(3) Kjellström, op.cit., p. 21.

(4) Fransson, F.: paper given at the symposium of the International Folk Music Council, Stockholm 1969.

(5) Kjellström, op.cit., p. 22.

(6) Ling, J. and Jersild, M.: "A method of cataloguing vocal folk music", ARV, Stockholm 1965.