PARTICULAR ANALYSIS OF SOUND SIGNALS ON DEVICE YAMAHA PSR E463

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ABSTRACT

The mathematical statistics fulfils a significant role in our lives. The multidisciplinary impact can be seen in a wide spectrum of areas e.g. engineering, medicine, humanity sciences. In this article, the particular analysis of sound signals is presented. The proposed analyses are bound on device Yamaha PSR E463. The methods of mathematical induction are utilized on data of software Audacity. The spectral density function is measured. The confidence intervals of descriptive aspects of them are achieved. The normality of data of spectral density signals is proposed. Autocorrelations, cross correlations of spectral density functions are drawn. In accordance of normality of data, then the multiple sample tests ANOVA or Kruskal-Wallis's test are used. For purposes of paired testing of two spectral density functions, the Mann-Whitney test or Wilcoxon paired test is used. The main idea of the article can transfer, that particular statistical analysis can be useful and suitable tool, how to understand the context of the applied acoustics.

1. INTRODUCTION

The mathematical statistics [1-12] fulfils a significant role in our lives. The multidisciplinary impact can be seen in a wide spectrum of areas e.g. engineering [13-24], medicine [25], humanity sciences [26-38]. The difference is based on statistical significance level alpha [39]. For purposes of quantitative humanity science research is determined alpha as 0.05. In an area of engineering is 0.01 and in medicine is 0.001.

In the quantitative research, the p-value [40] is obtained. The p-value is then compared with the statistically significant level alpha. If the p-value is greater than alpha, then the zero hypothesis is failed to be rejected. In the opposite case, the zero hypothesis is rejected in favour of the alternative hypothesis. The hypotheses can be focused on testing the normality of data [41], determination of confidence intervals [42], paired testing [43], two-sample or higher-sample tests [44].

In this sense of testing hypotheses, the paired comparation [43] can be useful. If data fulfils the normality [41], then the paired T-test [43] is used. In the opposite case, the Wilcoxon paired test [43] is applied. In the acoustic research, the comparison of two signals can be appropriate. Where the normality test [41] is Shapiro-Wilk test.

The declaration of included frequencies can be obtained in the form of spectral density functions [45]. This information can help to understand the background of structure of the sound signals [46-50]. This data can be achieved in the form of exported table in the sound software e.g. Audacity [51].

In this article, the particular analysis of sound signals is presented, as cannot be widely seen. The proposed analyses are bound on device Yamaha PSR E463. The methods of mathematical induction are utilized on data of software Audacity and provided in the statistical software PAST Statistics 5.0.

The spectral density function [45] is measured. The confidence intervals of descriptive aspects [42] of them are achieved. The normality of data [41] of spectral density signals [45] is proposed.

For purposes of obtained data of signal boundness, the autocorrelations [52], cross correlations [53] of spectral density functions are drawn. In accordance of normality of data, then the multiple sample tests ANOVA or Kruskal-Wallis's test [44] are used. For purposes of paired testing of two spectral density functions, the paired T-test or Wilcoxon paired test is used.

The main idea of the article can transfer, that particular statistical analysis can be useful and suitable tool, how to understand the context of the applied mathematics.

2. METHODS

The methodology background is based on the principles, which can be seen in the frame of the quantitative research [1-12]. In the case of presented methods, the system of comparison the p-value [40] with the significance level [39] is utilized. With regards to these comparisons, the acceptation or rejection of a zero hypothesis is appeared. Whether the p-value is greater than statistically significance level, then the zero hypothesis is accepted. In the opposite case, the zero hypothesis is rejected in favour of the alternative hypothesis. In the humanities areas [26-38], the level is 0,05. In the engineering sciences [13-24], the level is 0,01. And, in the medicine [25], the level is 0,001. Before testing the hypotheses, the normality [41] of input data must be measured. For these purposes, the Shapiro-Wilk or Anderson-Darling test [41] is applied. For the normal distributed data and for non-normal distributed data, the other tests of hypotheses are used. Whether data fulfils the normality assumption, the parametrical test are used. In the opposite case, the non-parametrical tests are proceeded. In the article, tests of normality, two and higher sample tests [44], two sample paired tests [43] are processed. For two sample tests, are T+F test or Mann-Whitney test [44] are considered. For higher sample test, the ANOVA or the Kruskal-Wallis [44] tests are bounded. For two sample paired tests, the paired T test or the Wilcoxon paired test [43] are used.

In the software Audacity [51], the spectral density function [45] of input sound signals [46-50] is measured. The spectral density functions can characterize and analyse the included obtained frequencies of proposed signals. The accords C dur, D dur, F dur and a mol are further analysed for the change repertoire – for a piano, for a flute and for a saxophone. Each tool is measured alone, and the global comparison is offered. The source of signals is the Yamaha keyboard PSR 463, which is connected with the computer by the USB connection. From the Audacity software, data is exported to the text format, which includes two columns: the frequency and the spectral density function. Then data can be imported to the software MS Excel and to the software PAST Statistics.

The analysis in MS Excel is the graphical interpretation of the spectral density functions across the tools and accords. In the software PAST Statistics, the normality tests [41], bootstrap statistical characteristics [42] considered on the confidence intervals, the autocorrelation functions [52], the cross-correlation functions [53] and the cluster analysis [54] is processed.

At first, the spectral density functions are drawn in plots in MS Excel, for pairs C dur & D dur, C dur & F dur, C dur & a mol in case of input sound of the piano, the flute and the saxophone. These pairs are analysed in software PAST Statistics on the normality, bootstrap pointers on the confidence sense, Mann-Whitney test and Wilcoxon paired test. For the considered pairs, the autocorrelation and cross-correlation function is drawn by PAST. Then these pairs of autocorrelation functions are compared by the Wilcoxon paired test after analysis of normality.

For the accords C dur, D dur, F dur and a mol, the tools piano, flute and saxophone are considered as higher samples of the spectral density functions. Therefore, the Kruskal-Wallis test is applied. For the descriptive characteristics of tools, the cluster analysis for each accord is then provided. On the plot of this cluster analysis the neighbourhood sources can be classified. All these tests are computed in the software PAST Statistics 5.0, which is free available.

3. RESULTS AND DISCUSSION

In this section, source signals from piano (Subsection 3.1), flute (Subsection 3.2) and saxophone (Subsection 3.3) are analysed using by the spectral density functions. These spectral density functions are further compared using by Wilcoxon paired tests. In the next step, the autocorrelation function of the spectral density functions is drawn and compared also by the Wilcoxon paired tests. In the subsections **3.1 – 3.3**, the pairs of spectral density functions of signals C dur & D dur, C dur & F dur, C dur & a mol are analysed. In the **Subsection 3.4**, the global analysis is proposed in favour of Kruskal-Wallis test comparisons and the cluster analysis.

3.1. PIANO

For the source signal of piano, the bootstrap confidence intervals can be seen in **Table 1** for C & D Dur. For these accords the spectral density functions (**Figure 1**) are similar on the statistically significant level 0.05, which can be achieved after provided Mann-Whitney (**Table** 3) and Wilcoxon paired test (**Table 4**). Normality tests (**Table 2**) are negative.

	C Dur	Lower conf.	Upper conf.	**D Dur**	Lower conf.	Upper conf.
N	**511**	511	511	**511**	511	511
Mean	**-104,538**	-106,1708	-102,9397	**-103,889**	-105,5252	-102,3242
Std. error	**0,81259**	0,7347702	0,883549	**0,817785**	0,7416558	0,8858625
Variance	**337,4148**	275,8824	398,9166	**341,7427**	281,0772	401,0084
Stand. dev	**18,36885**	16,76404	20,12708	**18,48628**	16,91245	20,16552
Median	**-113,983**	-114,2116	-113,819	**-113,897**	-114,3619	-113,635
Skewness	**1,852378**	1,561453	2,107275	**1,739381**	1,476253	1,978305
Kurtosis	**2,447188**	1,049602	3,504339	**2,038577**	0,8378013	2,993161

Tab. 1. Bootstrap Confidence Intervals for C & D Dur.

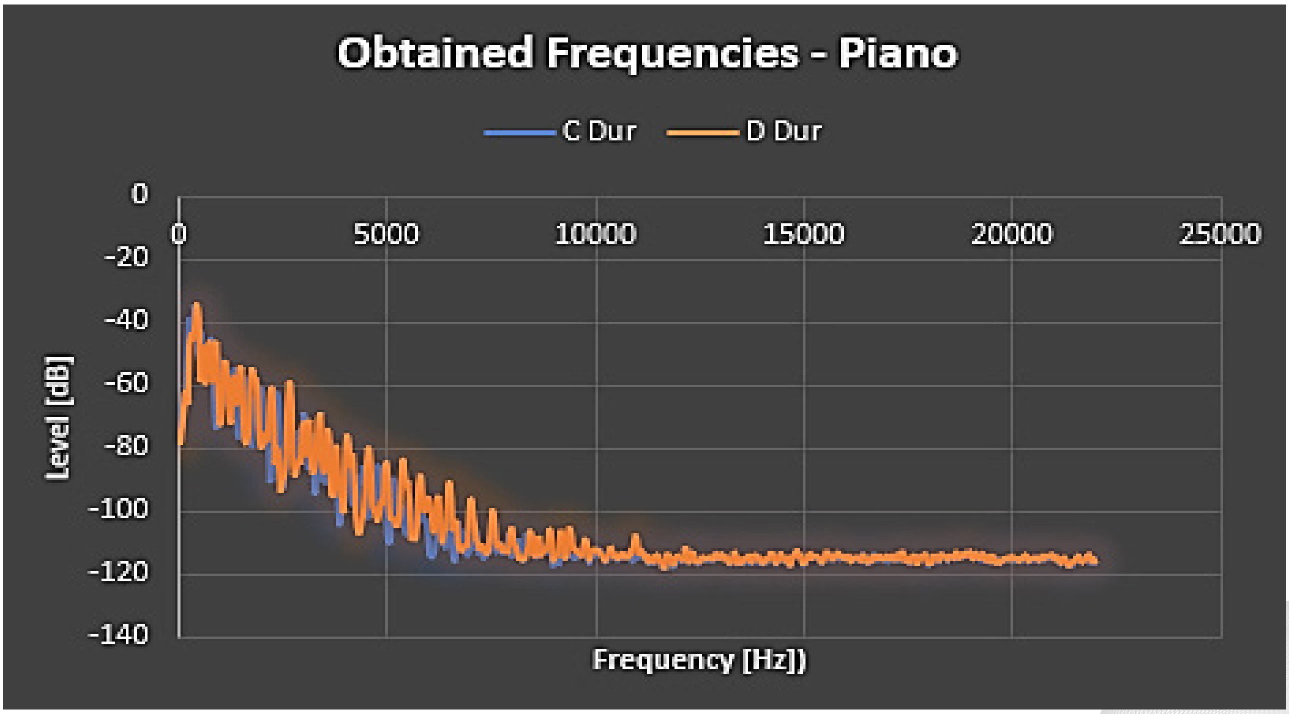

Fig. 1. Spectral Density Functions of C Dur & D Dur

	C Dur	D Dur
N	511	511
Shapiro-Wilk	0,66	0,6885
p(normal)	1,16E-30	1,28E-29
Anderson-Darling	74,19	66,71
p(normal)	8,59E-140	9,24E-130
p(Monte Carlo)	0,0001	0,0001
Lilliefors L	0,3161	0,2895
p(normal)	0,0001	0,0001
p(Monte Carlo)	0,0001	0,0001
Jarque-Bera JB	414,3	341,9
p(normal)	1,06E-90	5,67E-75
p(Monte Carlo)	0,0001	0,0001

Tab. 2. Achieved Negative Normality Tests

C Dur	D Dur		
N:	511	N:	511
Mean rank:	253,23	Mean rank:	258,27
Mann-Whitney test for stochastic equality			
U :	1,28E+05		
z :	0,54619	p (equal):	0,58493
Monte Carlo permutation:	p (equal):	0,5847	

Tab. 3. Mann-Whitney Test with Confirmation of Similarities of C&D Dur

For the spectral density functions of C & D Dur were drawn the autocorrelation functions (**Figure 2**) and one cross-correlation function (**Figure 3**). Here can be seen similarities, which can be seen also in the **Table 5** as achieved results of Wilcoxon paired test.

C Dur	D Dur		
N:	511		
Mean:	-104,54	Mean:	-103,89
Median:	-113,98	Median:	-113,9
Wilcoxon test for stochastic equality :			
W :	62167		
Normal appr. z :	-0,97051	p (equal):	**0,33179**
Monte Carlo (n=99999):	p (equal):	0,33299	
Exact test not executed (N>22)			
Vargha-Delaney A effect size:	0,5029 (small)		

Table 4. Wilcoxon Paired Test with Confirmation of Similarities of C&D Dur

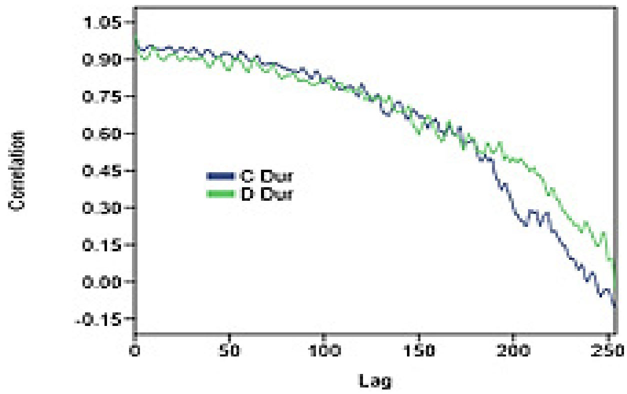

Fig. 2. Autocorrelation Functions of C & D Dur Signals

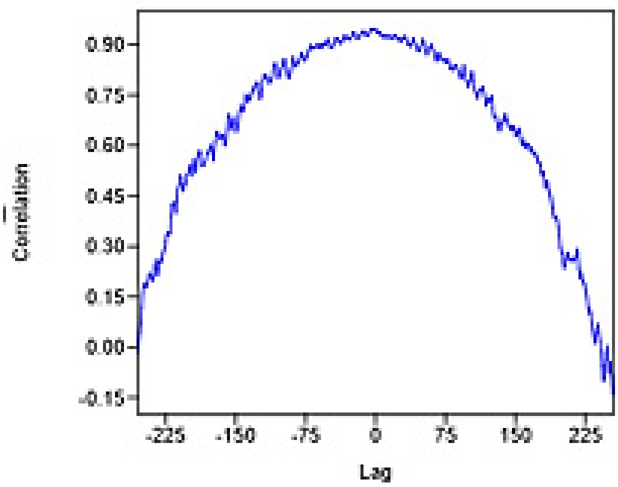

Fig. 3. Cross-Correlation Function of C & D Dur Signals

For the spectral density functions of C & F Dur (**Figure 4**), and C Dur & a mol (**Figure 5**) did not identified the similarities using by Mann-Whitney (p-value 0,00052204) and Wilcoxon paired tests (p-value 3,8997E-32). Also, similarities across the autocorrelation functions (**Figure 6 - 7**) were not obtained (p-value < 0,05).

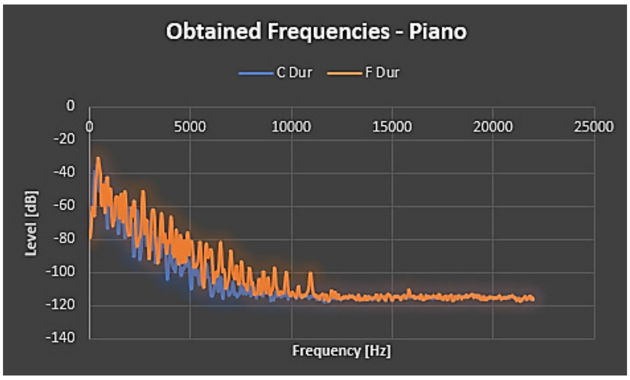

Fig. 4. Spectral Density Functions of C & F Dur

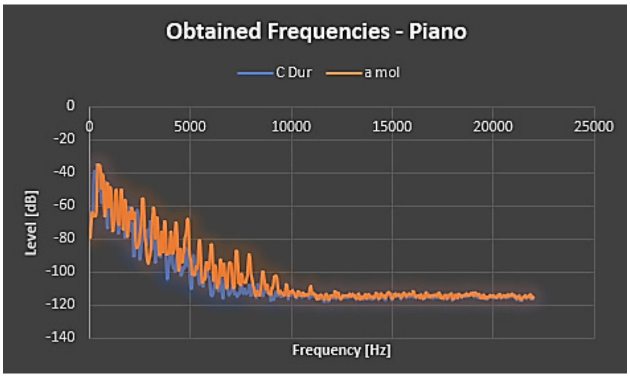

Fig. 5. Spectral Density Functions of C Dur & a mol

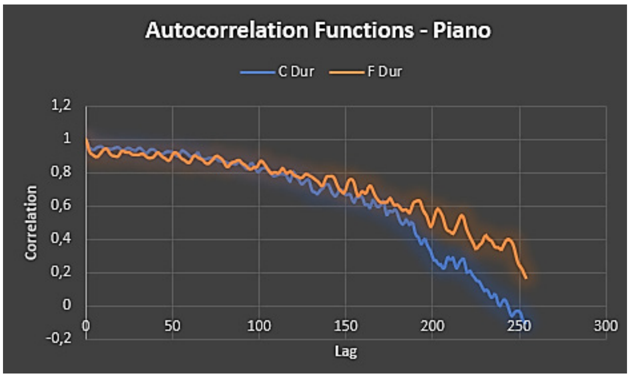

Fig. 6 Autocorrelation Functions of Spectral Density Function of C Dur & F Dur

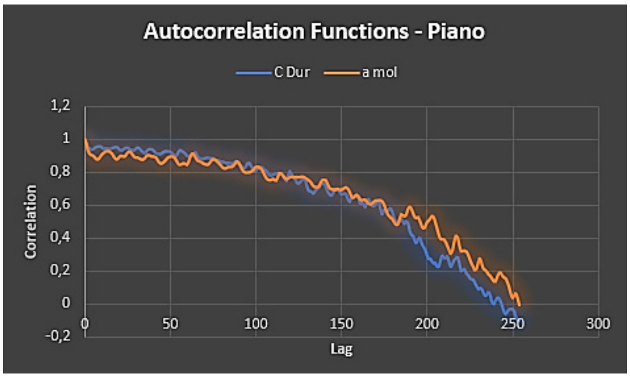

Fig. 7. Autocorrelation Functions of Spectral Density Function of C Dur & a mol

3.1. FLUTE

For the spectral density functions of C & D Dur (**Figure 8**), C & F Dur (**Figure 9**), and C Dur & a mol (**Figure 10**) did not identified the similarities using by Mann-Whitney (p-value <0,05) and Wilcoxon paired tests (p-value <0,05). Also, similarities across the autocorrelation functions (**Figure 11 - 13**) were not obtained (p-value < 0,05).

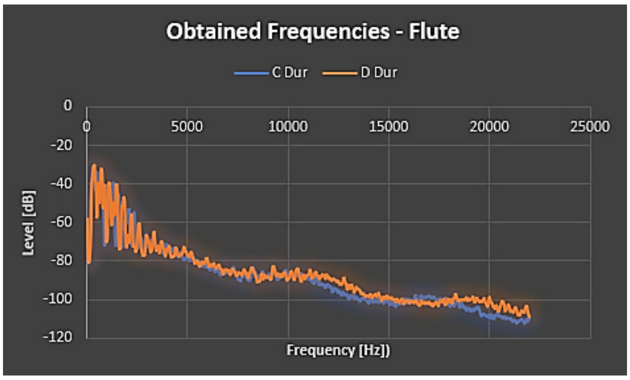

Fig. 8. Spectral Density Functions of C & D Dur

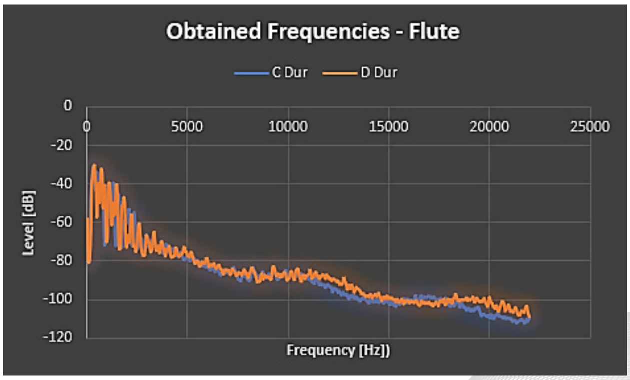

Fig. 9. Spectral Density Functions of C & F Dur

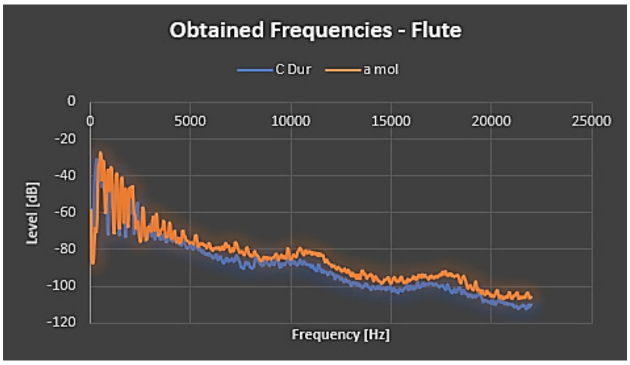

Fig. 10. Spectral Density Functions of C Dur & a mol

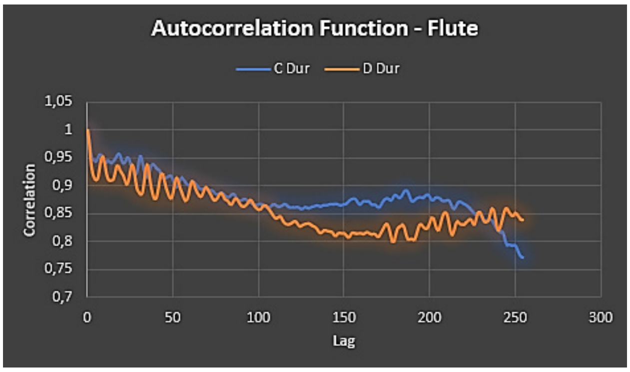

Fig. 11. Autocorrelation Functions of Spectral Density Function of C & D Dur

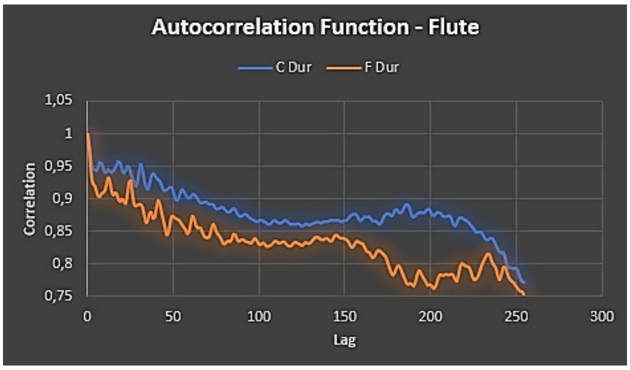

Fig. 12. Autocorrelation Functions of Spectral Density Function of C & F Dur

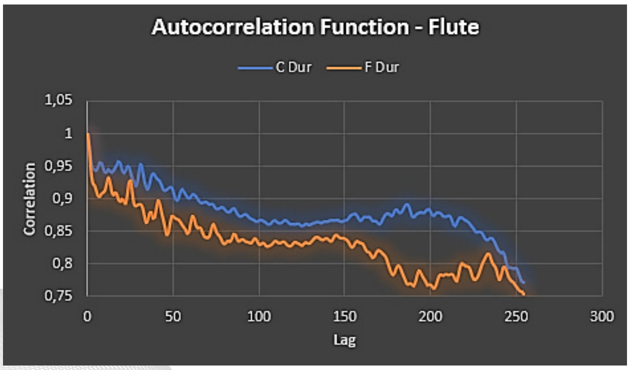

Fig. 13. Autocorrelation Functions of Spectral Density Function of C Dur & a mol

3.3. SAXOPHONE

For the spectral density functions of C & D Dur (**Figure 14**), C & F Dur (**Figure 15**), and C Dur & a mol (**Figure 16**) did not identified the similarities using by Mann-Whitney (p-value <0,05) and Wilcoxon paired tests (p-value <0,05). Also, similarities across the autocorrelation functions (**Figure 17 - 19**) were not obtained (p-value < 0,05).

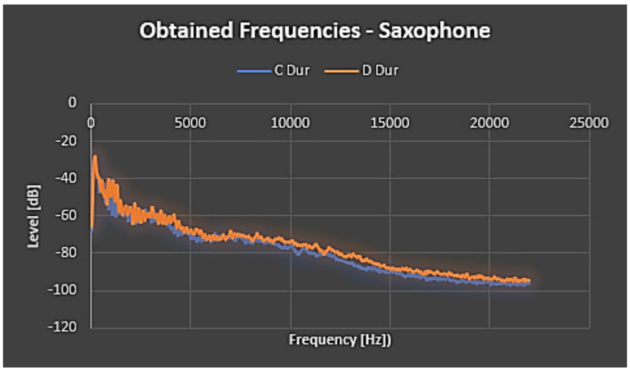

Fig. 14. Spectral Density Functions of C & D Dur

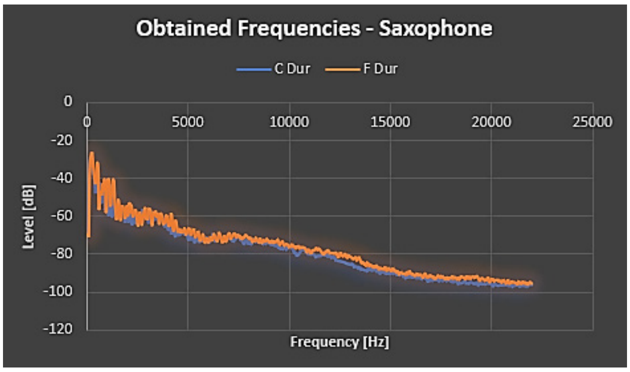

Fig. 15. Spectral Density Functions of C & F Dur

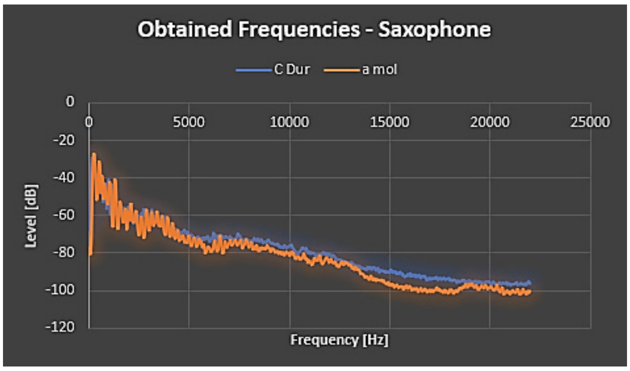

Fig. 16. Spectral Density Functions of C Dur & a mol

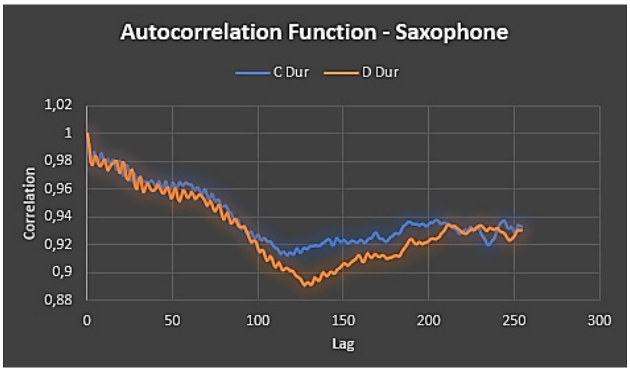

Fig. 17. Autocorrelation Functions of Spectral Density Function of C & D Dur

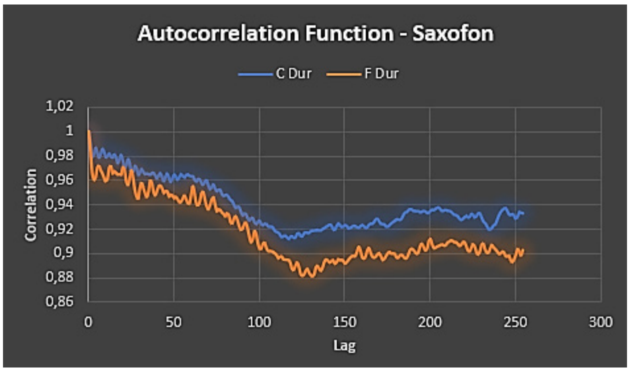

Fig. 18. Autocorrelation Functions of Spectral Density Function of C & F Dur

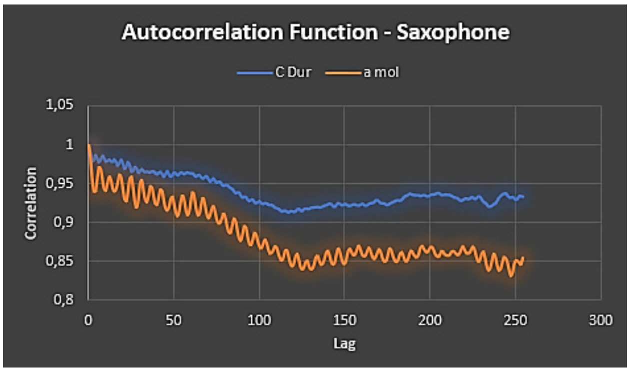

Fig. 19. Autocorrelation Functions of Spectral Density Function of C Dur & a mol

3.4. GLOBAL ANALYSIS

For the spectral density functions of C Dur (**Figure 20**), D Dur (**Figure 21**), F Dur (**Figure 22**) and a mol (**Figure 23**), the differences across source of signals Piano, Flute and Saxophone were compared using by Kruskal-Wallis tests with result of p-value <0,05.

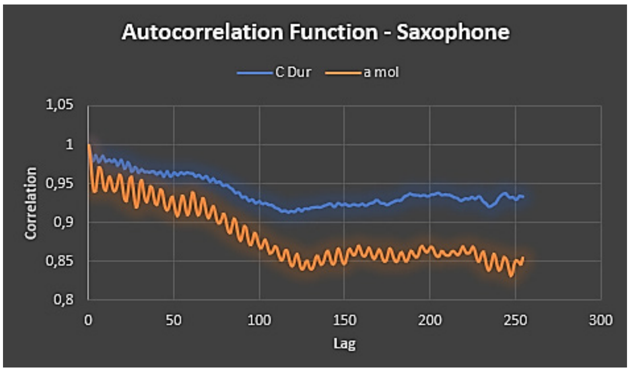

Fig. 20. Spectral Density Functions of Sources across C Dur

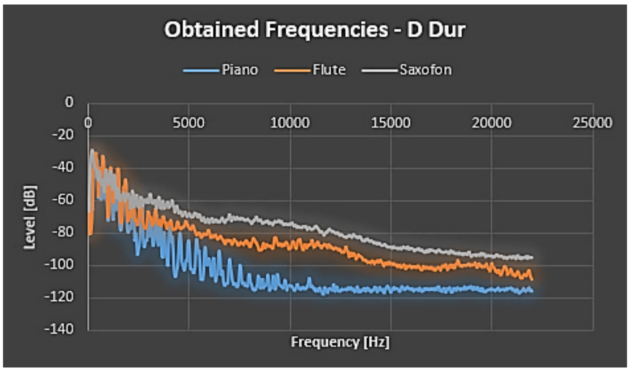

Fig. 21. Spectral Density Functions of Sources across D Dur

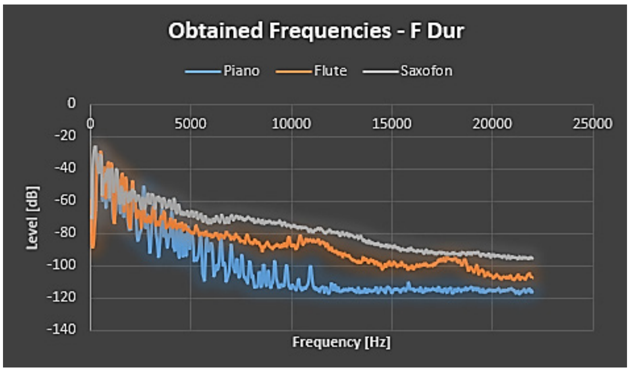

Fig. 22. Spectral Density Functions of Sources across F Dur

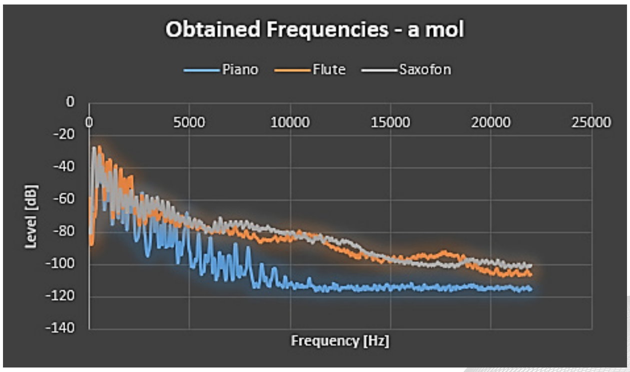

Fig. 23. Spectral Density Functions of Sources across a mol

The similarities of sound sources across accords can be systematically drawn using by Cluster analysis (**Figure 24**), where the Euclidean distances was measured. Positively, the groups are corresponding the aim of this work.

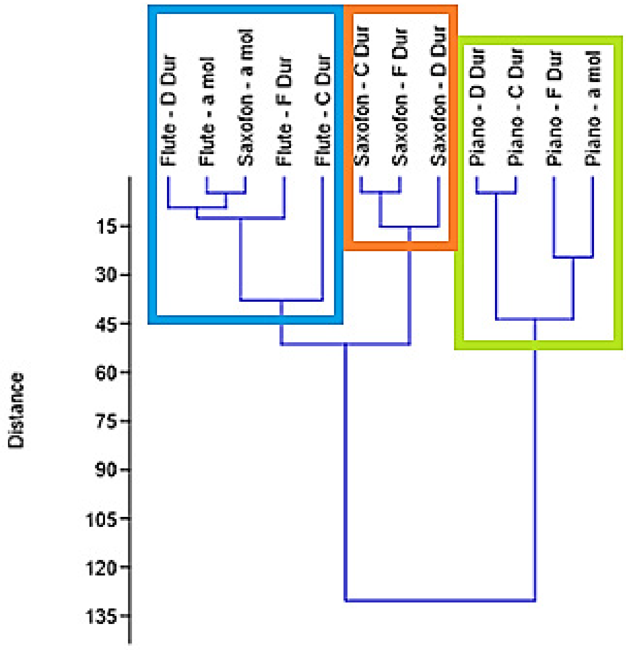

Fig. 24. Cluster Analysis Across Sound Sources and Accords

4. CONCLUSION

Across signal sources of device Yamaha PSR E463 (Piano, Flute, Saxophone), the statistically significant similarities were identified on the significance level 0,05. The particularly based signals were accords C Dur, D Dur, F Dur and a mol. The spectral density functions of these signals were measured by the software Audacity. The autocorrelation functions of spectral densities were computed using by software PAST Statistics 5.0, when all statistical tests were also provided in this tool. **Similarities** were identified by **Piano C & D Dur**, where p-value was > 0,05. The bootstrap confidence intervals were measured for the spectral density function, also the normality of data was presented. The similarities were identified using by the Mann-Whitney and Wilcoxon paired tests. Also, the positive result was achieved by comparison of autocorrelation functions of spectral density functions. Repeatedly, the Wilcoxon paired test obtained positive results. Other sound sources across accords were **negative** with statistical computations of described tests on the p-value < 0,05. In the sense of global comparison, also the outputs were in the Kruskal-Wallis test rejected. More positively, the cluster analysis was obtained, where the sources across accords were grouped systematically. The main idea of this article was to point on possibilities of the statistical computations in the area of processing the sound signals.

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