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TOWARDS A MULTIMODAL ANALYSIS OF EUROPEAN PIANO SCHOOLS OF MUSIC PERFORMANCE

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Abstract: **This study aims to characterize representative performances by experienced pianists in order to determine main influential trends in performance, derived specifically from traditional piano practices referred to as National Piano Schools. The methodology of this exploratory study departs from a musicological empirical analysis in articulation with recent technological developments for metric methods. It allowed an analysis of gesture and musical semantics by applying a multimodal approach for capturing the pianist performance based on the extraction of features' sets specifically targeted to each piano school. In this paper we describe the quantitative analysis approach based on motion capture.**

Keywords: **Music performance; European Piano Schools; Motion Capture; Multimodal analysis**

1. INTRODUCTION

Previous research [1] has shown strong musical correlation of particular characteristics, namely the aesthetic, the technical, the historic and the repertoire. Overall the main national piano schools consist of three essential branches: the Russian school; the French school; the German school. The identification of national piano schools provides a powerful framework of study and awareness of the main influential European music intangible heritage.

In the beginning of the 21st century performers and audiences were confronted with versatile piano practices originated from diverse nationalities and generations. Several studies have shown that it is possible to identify major trends in piano performance. These are generally referred to as national piano schools, due to its strong correlation to particular characteristics, which seem to share common features within communities of practitioners. Facets such as aesthetics, technique, historical tradition and chosen repertoire have been studied by several researchers [2], [3], [4], [5]. Overall the main National Piano Schools consist of three essential branches: the Russian school, the French school and the German school [6], [7]. It is acknowledged that these national piano schools are present in most of the piano performance practices in the 20th century and therefore its identification provides a powerful framework to study, understand and raise awareness of the European music intangible heritage. A live performance is much more than a sonic event. Pianists use the whole body to enhance their communication of the music's spiritual, emotional and dramatic essence in straight connection between muscular contractions and the overall body posture. Many of the studies concerning piano performance body posture descriptors were of poor methodological quality concerning validity and reliability of methods, the findings of these studies should be interpreted with caution. This means more methodologically sound research is necessary. Ortmann [8], [9]. point to the desirability of coordination of the entire neural system with corresponding response in movement in the torso as well as the arm, hand, and fingers, account for muscular tension and fixation in joints at a time when focus was directed toward relaxation and freedom of movement. Further studies focuses on use of arm weight at the keyboard and arm movements as well as shoulder and torso flexibility, upper arm, shoulder and torso [9], use of arm weight, relaxation and musical interpretation [10]. The data extraction will be an important tool for comparison of database results concerning to objectively evaluate and characterize representative performances by experienced and skilled pianists in order to determine the main influential trends of their performance practice.

On the other hand, recent technological developments brought into the musicology research field new metric methods and instruments that allow an accurate analysis of musical semantics. Techniques like research in Music Information Retrieval [11], [12] and Motion Information Retrieval allow a better awareness of the performance practice providing a new framework for application design, such as in Sonic Interaction Design, Content Based Recommendation Systems or Expressive Generation of Musical Content. This project aims to objectively evaluate and characterize representative performances by experienced and skilled pianists of each piano school, based on a set of features extracted using a multimodal analysis approach. Following up to the work developed by Lourenço [1] concerning the characterization of piano schools using a musicological approach, it will now be possible to accurately analyze and evaluate actual metric data combining MIDI, video footage and high resolution digital audio. This multimodal approach goes beyond traditional case studies since it allows the correlation of data acquired from different sources with great potential for new insights on this specific study (i.e. characterizing piano performance according to European piano schools).

In this paper we describe the motion capture results of quantitative analysis of data of the chosen repertoire works by J. S. Bach *Präludium C- Dur BWV 846* (1722) and F. Chopin, *Nocturne Es Dur op. 9 no. 2* (1830-31). Other modes of data are there for further multimodal analysis.

2. METHOD

2.1. Participants

The first experiment was conducted with 9 subjects ranging from 19 to 50 years old with professional classical piano training. In this paper we will present the most significant results.

Four piano mainstream repertoire works have been chosen for the tests with the 9 pianists. Works J. S. Bach *Präludium C- Dur BWV 846* (1722), J. Haydn, Sonate C-Dur 1st and 2nd Movement, F. Chopin, *Nocturne Es Dur op. 9 no. 2* (1830-31), C. Debussy, *Danseuses de Delphes* (1910). This chosen repertoire intended to cover the main piano music stylistic diversity in order to recognize the possible influential trends of piano performance. Namely, baroque, classical, romantic and modern styles.

2.2. Materials and Procedure

For this research the applications of data analysis in musicology is a promising approach because it allows us to analyze data from

many different dimensions, categorize it, and summarize the relationships identified thus allowing to discover hidden regularities of both music and performance practice. This technique combines acquisition of finger movement and articulation captured by haptic interfacing with a Disklavier Piano (Yamaha Grand Piano that provides logic data from finger stroke pressure) and capture of movement, clean-up of data post-processing of data (it can appear as two-dimensional or three-dimensional objects) using MOCAP (Motion Capture) of each pianist analyzed, body motion descriptors by software analysis of digital recording of video footage and musical performance features extracted by software analysis of high resolution digital audio. Later on with this data, it will be possible to analyze and process the acquired descriptors data mining computational models in order to extract significant results from correlating the extensive multimodal datasets. The hosting institution for this post-doctorate research internship, Research Center for Science and Technology of the Arts (CITAR) at Catholic University of Porto has at its disposal an optical motion capture system (Vicon). The research group, on music performance studies and digital art provides an ideal research framework to conduct the project.

For this first experiment the postproduction of this ongoing project is a work on progress. What is important here, and what has a major gain is the approach used to make a precise quantitative analysis of musical movements and especially of national piano schools.

This technique combines acquisition of capture of movement (which of course includes the actual performance) cleanup of data post-processing of data (it can appear as two-dimensional or three-dimensional objects) 9 pianists playing on a Disklavier Piano (*Yamaha Grand Piano* that provides logic data from finger stroke pressure) using MOCAP (*Motion Capture*). The figures extracted from MOCAP device show amplitudes (percentiles) for each pianist, on each piano piece performed, 4 piano mainstream repertoire works, which have been chosen for the tests with the 9 pianists. The figures extracted from MOCAP device show amplitudes (percentiles) for each pianist, on each piano piece performed, 2 piano mainstream repertoire works, which have been chosen for the tests with the 9 pianists.

For this first test, we recorded data that were made in August 2013, including the files of the Blade (program Vicon). The post production and data the part of reconstruction and post-production data, which consists of reconstructing, identifying (labeling process of the Blade), associating a virtual skeleton and export, and the other one to turn into part of metric data. Blade rebuilt the data, that is, information of markers is captured when the computer is recorded in two-dimensional space. When we open the project (take), the only information we have access to is the results of 10 cameras with x and z coordinates. We reconstruct three-dimensional shape information of the cameras, whereas a minimum 2 to 3 camera is necessary to define a point in three-dimensional space.

The quality of capture is defined by the amount of existing cameras for the actual number of markers (53 performer), the placement of the cameras in space in relation to markers and occlusions in existing catch, from the type of movement (for example ex rolling on the floor) and/or the positioning of the cameras. Piano occlusion makes the legs and the hands on some cameras (half of which is on the other side).

The cameras should have been placed above the hands and beneath the piano (another set), in order to optimize the quality of the capture. Therefore, the process of "labeling" (identification), wherein the associate "markers" (virtual markers) to 53 "labels" (labels) in the case of this project was a difficult process since the method was not an optimized capture to include a piano to occlusion of the markers.

The amount of virtual markers arrived at by thousands times to take, that had to be converted into labels 53, giving rise to a significantly greater margin of error, and to a process extremely long post-production.

Figure 1. Motion capture session

At an intermediate process, the joints were exported to Autodesk Maya, to create an "animation snapshot" which is a "cloud" of motion that corresponds to the overall visual range of motion. This conversion is a visual that groups the total of all "frames" (frames) of the take on a "frame" only. The frequency of frames per second is 25 in this case. The result is a "sculpture" of the movement, which can be compared to other takes and see what differences the amplitude of movement of different performers (as moved his head or arms) without having to play the entire musical example.

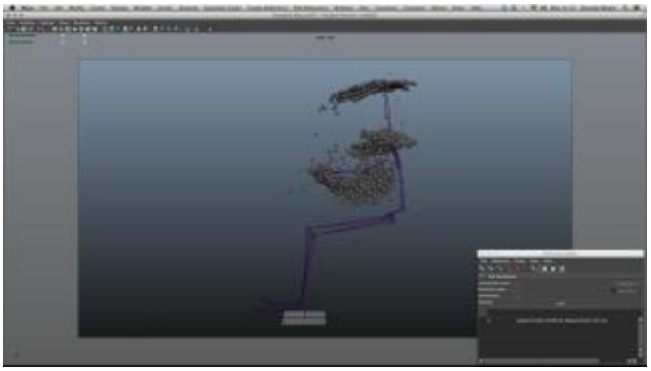

Figure 2. Visual range of motion

After pre-processing of this data, we went on to a quantitative analysis importing data to Matlab.

The extraction of features continued, different percentiles calculated on the trajectories of differents points of the body, on each axis allowing to compare pianists and reveal their national piano schools.

The metric analysis of data and amplitudes (percentiles) for each pianist performance, on each piano piece considered: axis 1 = horizontal axis along the keyboard, from left to right. (joints moving left and right, with respect to the keyboard); axis 2 = horizontal axis perpendicular to the first. (joints moving forward and backward, with respect to the keyboard); Axis 3 = vertical axis. (joints moving up and down). Percentile (90%): the percentile is based on the distribution of the positions of each joint along the rendition. The percentile 90% is the interval centered on the mean of the sample, covering 90% of the data of the sample. For each joint, the percentile is calculated, ignoring miscaptured frames. For joints too badly captured, the percentile is not shown.

The first component lost a bit of significance (57% of information, 61% before). On the first component we see that Pianist 3 is really close to Pianist 1 and Pianist 9, meaning that the first component is quite linked to the bust criterion, and not to the arm-weight criterion (it is actually quite linked to the general amplitude of every joint in every sense).

A distinction between two main comparison criteria found in the previous part has been done:

- Bust criterion (x and y-axes of neck, trunk and both shoulders);
- Arm-weight criterion (z-axis of both elbows and both hands).

Analysis has been done on these comparison criteria (some results follow), still a work in progress on an ongoing project.

a. Arm-Weight Criterion

Arm-weight criterion distances the 1st PC (62.5% of information) shows now that Pianist (3) could eventually be placed on the Russian school tendency in the arm-weight criterion. However, according to the 2nd PC (28.3% of information) Pianist (3) is not so far from Pianist (1) and Pianist (9). This is probably due to the fact that their hands move the same way. Pianist (3)'s right hand move more than his left like them. The interpretation of these principal components (PCs) tells us that PC1 (62.5% of information) corresponds to general amplitude of arms. PC2 (28.3% of information), difference between left arm and right arm amplitudes. PC3 (7.3% of information) and difference between elbows amplitudes and hands amplitudes. The arm-weight technique can thus be divided in these three important sub-criteria. PC2 is in fact also interesting as an artistic point of view. The importance of one hand in respect to the other, that is in general balance of bass and high notes, can be an important feature of the sonority of a piece, and can be a signature of a pianist.

b. Bust Criterion

In this case, the 1st PC is clearly dominant (92% of information), and indicates here that Pianist (3) is an extreme and Pianist (5) is another extreme. Pianist (1), Pianist (8) and Pianist (9) are close to Pianist (3) (still bust), and Pianist (4) is quite close to Pianist (5) (stirred bust).

This difference is rather stronger on Chopin than on Bach performances of the pianists. The biggest differences are found for Pianist (8) and Pianist (9). We can say that pianists do not necessarily play the same way on both pieces but there might be a little tendency for some pianists to be generally more still and others more agitated. The analysis must be deepened to confirm or infirm this tendency.

Table 1. Calculated motion distances between pianists regarding three axis

	1	2	3	4	5	6	7	8	9
1	0	1.3814	1.2480	1.2926	2.4177	1.2140	0.7987	0.8877	0.3056
2	1.3814	0	1.2079	0.5884	1.9628	0.4256	0.5827	0.4938	1.3470
3	1.2480	1.2079	0	0.9099	1.1697	1.6335	1.4159	0.7564	1.2190
4	1.2926	0.5884	0.9099	0	1.4834	0.7834	0.7984	0.5050	1.2582
5	2.4177	1.9628	1.1697	1.4834	0	2.1820	2.2918	1.7147	2.3887
6	1.2140	0.4256	1.6335	0.7834	2.1820	0	0.5593	0.8771	1.5141
7	0.7987	0.5827	1.4159	0.7984	2.2918	0.5593	0	0.6595	0.9548
8	0.8877	0.4938	0.7564	0.5050	1.7147	0.8771	0.6595	0	0.8532
9	0.3056	1.3470	1.2190	1.2582	2.3887	1.5141	0.9548	0.8532	0

3. RESULTS AND DISCUSSION

Observation of several amplitudes extracted from the data allowed us to compare the pianists. Results are listed as follows:

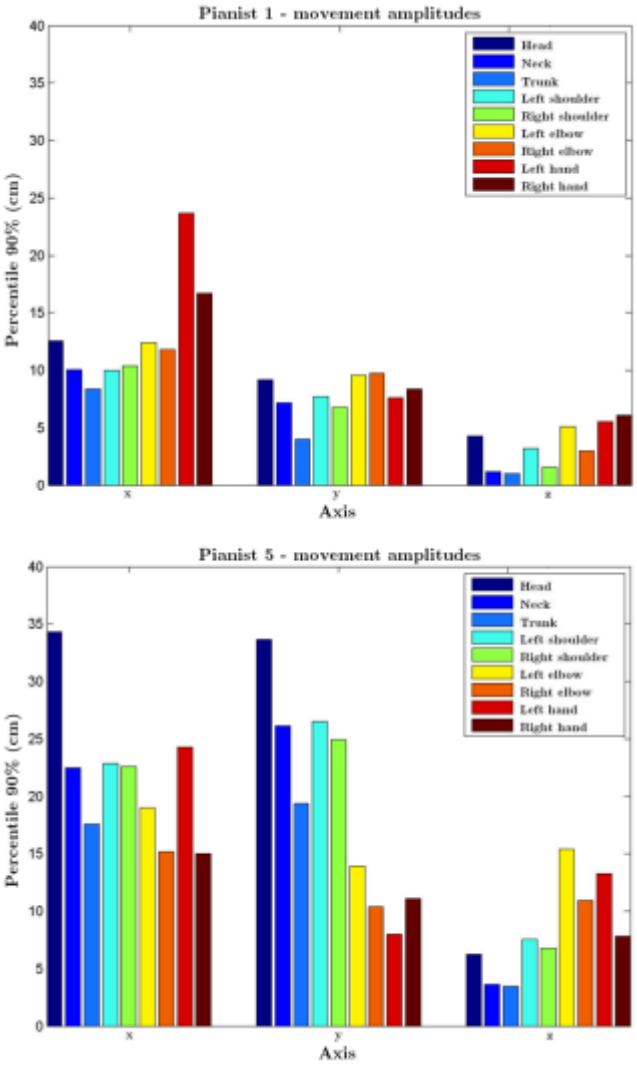

Figure 3. Results pianists extreme movement amplitudes

Fig. 3 shows the movement amplitudes for the most extreme pianists on Bach. Each bar represents the amplitude (percentile 90%) of one joint of the upper body on one axis. Observation of these graphs for the nine pianists allowed us to note that the most varying amplitudes for the nine pianists were the bust (head, neck, trunk and shoulders) on x and y-axes, and the arms (elbows and hands) on z-axis. According to these graphs, pianist 1 is the most still pianist (see Fig. 3) and can be categorized in the French interpretation school. On the opposite, pianist 5 is the most stirred pianist and seems to use more the arm-weight technique, typical of the Russian interpretation school as Lourenço refers (2005, 2011, 2012).

According to these graphs, we represent a pianist in a 27-dimension space. To see which ones of these dimensions are most significant, we performed a Principal Component Analysis on the nine recorded pianists.

Fig. 4 shows the first six principal components and their variance ratios.

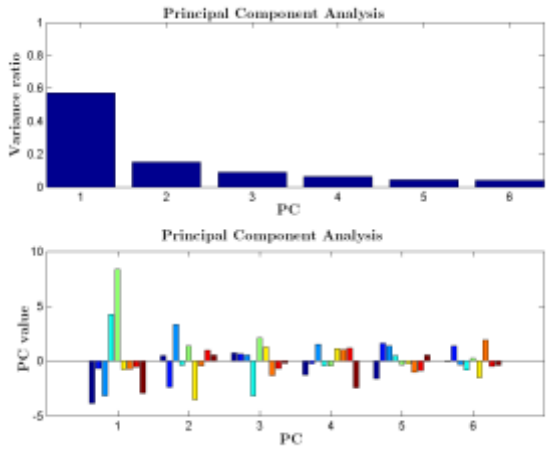

Figure 4. Principal Component Analysis

The first component has a variance ratio of 60%, meaning that data are much more scattered on the first component than on all the others. The first component is thus much more representative of the pianists than the others. The values of the first component allow easily comparing the nine pianists, and clearly showing that pianist 1 and 5 are the two extreme ones. The projection of the first component on the initial space (the 27 features) showed that this component clearly corresponds to the bust movement on x and y-axes. On the other hand, the second component indicates on which axis the bust is moving the most, that is more left-right or more backward-forward. The third component corresponds to the arm-weight technique that is if the pianist moves a lot his arms up and down.

Results show a correlation between the pianists who do not play the same way on most of the pieces and are generally more still and others more agitated. The same analysis was done on the rest of the database, but because of the too poor quality of the rest of the database, the results were not conclusive and comparison could not be done for all pieces.

4. Conclusions and Future Work

Further investigation with new data should thus be done. Nonetheless, the features that we extracted and analyzed seem to be relevant to compare pianists' way of playing, and maybe reveal different main national interpretation schools. Further tests will be necessary in order to deep analysis and to confirm or infirm this tendency. As an ongoing project of the precise quantitative analysis of musical movements and especially of national piano schools, further studies would benefit from a multimodal approach. The results themselves are not yet very conclusive (also because of the quality of the data).

Moreover, as pianists use their whole body to enhance their communication of the music's spiritual, emotional and dramatic essence, this project also aims to contribute into research on multi-disciplinary approach concerning issues of musicology, technology, computer science, biomechanics, cognitive psychology and performance practice.

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