Methodological Aspects of the Research in Musical Expressiveness Based on Corporal Movement Information

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***Abstract*—This project is focused on empirical analysis of musical expressiveness, based on information of musical content extracted from audio and video information of the musical performance, seeking to understand and to quantify the expressive intentions of the player.**

I. Introduction

Musical expressiveness is a concept witch is difficult to describe quantitatively, using objective analysis methods. In the last few decades, this problem has been studied using a method that aims at describing the expressive intentions of the musician, based on the audio analysis of his performances and more recently, also on the video analysis of these musical performances. The goal is to establish relations between the musician's expressive intentions and the acoustical and visual parameters extracted from the analysis.

The objective of this work is to propose a methodology that can be used to analyze corporal movement, finding relations between the physical gestures of the musician and his expressive intentions in a given musical performance. Clarinetists corporal movements were tracked, as they played classical pieces in their instrument, and then coherent and recurrent physical gestures were defined, based on a morphological and kinesthetic segmentation of these movements. The gestures found were then used to compare different interpretations of a musical piece, and also different parts of a musical piece.

The final objective is to incorporate a corporal analysis method into an acoustical musical expressiveness analysis tool, developed in earlier studies [3].

II. Data Acquisition

In this study, different performances of pieces of the classical clarinet repertoire were used. The pieces chosen were Mozart's Quintet for Clarinet and Strings, Kv 581 and Clarinet Concerto in A Major, Kv 622. Both pieces were performed solo by 3 professional clarinetists. The musicians were instructed to play the pieces is 3 different ways. First freely, as in a real concert situation. Secondly, following the beat of a metronome marking a quarter note and then following the beat of a metronome marking a half note.

The musician's body movements were tracked using a 3D high-end motion capture device, the Optotrak Certus. The audio was also captured synchronously using the same device. For now, the analysis was restricted to the head movements of the clarinetists. Four markers were used to define a rigid body representing the musician's head. They were mechanically coupled, using a light wooden frame, and attached to the musician's head. This system provides a set of coordinates representing the position of the rigid body in 6 degrees of freedom, 3 describing the position of it's centroid in cartesian space, and 3 describing it's rotation around each of it's axis. The sample rate used for the motion markers was set to 60 Hz and the audio sample rate was set to 10kHz.

III. Data Processing

A. Musical Note Segmentation

The precise detection of note onsets and offsets is not a trivial problem, even in monophonic musical signals, since the subjectivity in note discrimination cannot be ignored. The note onsets and offsets were detected using the RMS energy envelope curves, with a 23 ms analysis window and an adaptive energy threshold [2]. The extraction of the note fundamental frequencies can also aid the detection of the onsets and offsets, especially in the case of *legato* notes. The presence of transients during note transitions also made possible the use of spectral flow to aid the detection of note onsets and offsets. A combination and cross validation of these 3 methods provided a robust tool for note segmentation on the audio signals.

B. Movement Segmentation

The motion capture data was processed and used to extract several parameters of the clarinetists head movements, such as velocity, acceleration, displacement, distance, duration and trajectory centroids. The goal is to define coherent and recurrent physical gestures, based on patterns of the temporal and spatial evolution of these parameters, and then relate them to the musical score and to the musician's expressive intentions. This way it's possible to find out where the expressiveness information lies in the musician's corporal motion and how it relates to the structure of the musical piece been performed [1], [5].

The musicians performed the musical pieces sitting on a chair. In this condition, it's expected that the musician's head movements produce round trip trajectories around an

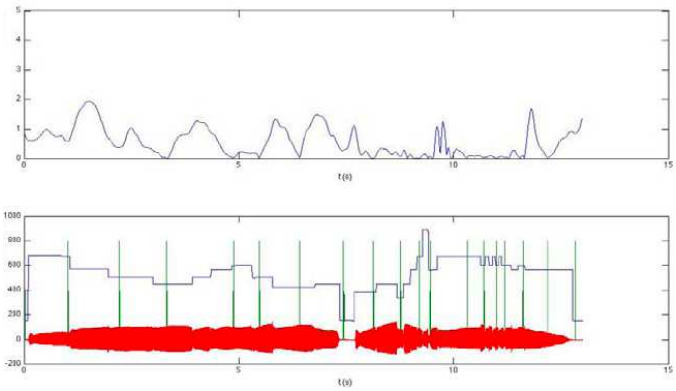

Fig. 1. Head movement segmentation by the velocity minima criteria for the half note metronome guided performance of Mozart's Quintet for Clarinet and Strings.

equilibrium position [4]. Considering that the ability to sustain movement in a given direction decreases as the musician's head moves away from the equilibrium position, there should be a drop in resultant velocity, related to a kind of direction shift on the motion. Based on this assumption, local minima on modulus of resultant velocity curve should be able to detect inflection points on the movement trajectories.

This simple method provided an efficient way to establish an initial segmentation of the musician's head movements. The modulus of resultant velocity of the musician's head was estimated using the euclidian distance between the positions of it's centroid along 2 subsequent samples.

Figure 1 shows the segmentation obtained by the velocity minima criteria, in a performance of a segment of Mozart's Quintet for Clarinet and Strings, in the case where the metronome was marking a half note. The upper graph shows the modulus of the velocity. In the lower graph, the blue curve represents the extracted pitch, the red curve represents the audio waveform and the vertical green lines indicate the segmentation points for the head movements of the clarinetist. In this analysis, 7 head movement segments were defined by the velocity minima along the first 2 musical phrases, that correspond to the first 4 bars of the musical piece.

Examining these segments in successive groups of 2 and 3, 3 physical gestures were identified, based on the well defined geometric structure of their trajectories, with clear beginning and ending points, delimited by direction shifts in the motion. The first of these gestures was composed only of the motion segment number 2. The second gesture was composed of the pair of motion segments 3-4 and the third gesture was composed of the pair of motion segments 6-7. The trajectories of each of these 3 gestures is showed in Figure 2, with the spatial coordinates given in millimeters. A red solid circle marks the beginning of each initial motion segment.

In a free performance of this same musical segment, without the presence of the metronome, a similar analysis identified only 2 physical gestures. The first gesture was composed of the first 3 motion segments and the second gesture was composed of the last 2 motion segments. The trajectories of each of these

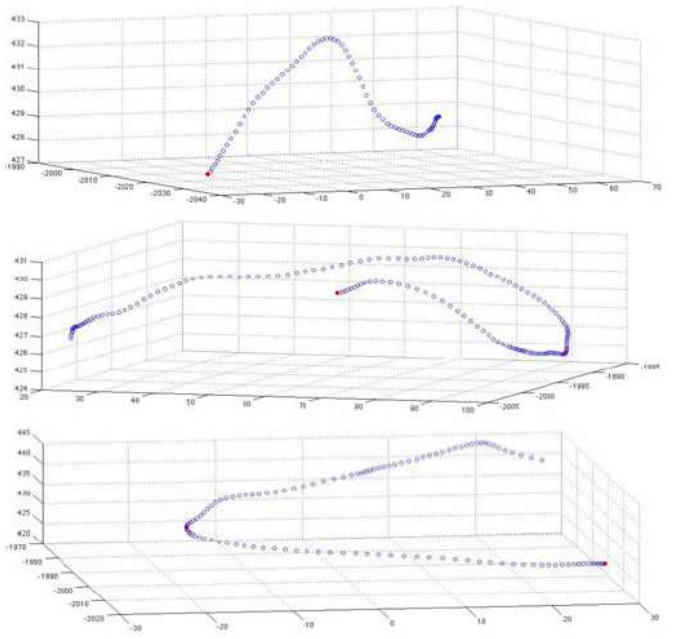

Fig. 2. Spatial trajectories of the 3 head gestures identified in the first 2 phrases of the half note metronome guided performance of Mozart's Quintet for Clarinet and Strings.

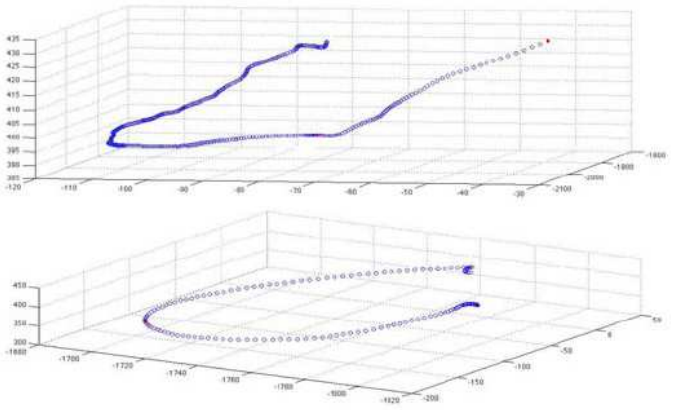

Fig. 3. Spatial trajectories of the 2 head gestures identified in the first 2 phrases of the free performance of Mozart's Quintet for Clarinet and Strings.

2 gestures is also showed in Figure 3.

The gestures defined in this analysis presented an important characteristic, that might also be used as another segmentation criteria after further investigation. Their trajectories tend to evolve along a given plane, in all of these cases.

IV. Results

A. Correlation Between Motion and Musical Structure

The segmentation points presented an approximate correspondency to some inflection points in the musical structure, like transitions between notes or phrases. In the first 2 phrases, the motion segments were better defined, with smoother velocity curves and clearer peaks and valleys. In these musical segments, specially in the metronome guided performances, it

was also noticed a certain periodicity in the velocity curves, that were also more related to the musical metric. Larger values for mean velocity and total duration time of the motion segments were also observed in this musical segment. The last phrases of this musical piece, on the other hand, presented noisy velocity curves, with small amplitudes an without clear peaks, valleys or evolution patterns. The motion segments in this part of the musical piece also presented smaller values for mean velocity and total duration time.

These observations suggest that the musician's head movements in the last part of the musical piece reveals less information related to his expressive intentions, if compared to what was observed in the first phrases of the piece. This probably occurs due to the simpler rhythmic and melodic structure of the first 2 phrases, and suggests that technically difficult musical parts might inhibit corporal movements and expressive intentions by the musician. Large amplitude ancillary movements could make the precise execution of the primary movements more difficult, compromising the sound production itself. On the other hand, musical phrases composed of longer notes and smoother transitions, like the first 2 in this piece, provide ideal conditions for expressive intentions to occur, trough the manipulation of note durations, intensities and timbres. This would be reflected in the ancillary movements, producing wider, longer and better defined physical gestures.

B. Correlation Between Motion and Expressive Intentions

Based on comparisons between the different performances of the first 2 phrases of Mozart's Quintet for Clarinet and Strings, it was observed that the motion segments were twice as long in time, without the presence of the metronome. The number of head gestures identified was also smaller in the free performance, and these gestures were also wider in space. The 3 gestures found in the metronome guided performance exhibited total displacements of 86, 98 and 96 millimeters, while the 2 gestures found in the free performance exhibited total displacements of 236 and 237 millimeters. In the metronome guided performance, the first 2 gestures exhibited durations of 1.2 and 2.6 seconds, staying inside the first musical phrase of the piece. In the free performance, on the other hand, the first gesture only, lasted for 6 seconds, going trough almost the whole first 2 musical phrases.

These differences in duration and extension of the gestures between the 2 styles of performance suggest a close relation between the gestures and the musician's expressive intentions. In these first 2 musical phrases, there are 2 inflection points in the musical structure, marked by harmonic resolutions, according to Figure 4. The first one is weaker, culminating at the relative tonic, while the second one is stronger, culminating at the tonic, after a faster melodic movement towards it.

In the metronome guided performance, the first 2 head gestures seem to be related to the first musical inflection point, while the third gesture is disconnected to the first 2, and seems to be related to the second musical inflection point. In the free performance, on the other hand, the long and wide first head gesture seems to be related to a preparation to the second and stronger musical inflection point, ignoring the first inflection point. Close to the second inflection point, occurs the second head gesture, that seems to be prepared by, and is directly connected to the first gesture. This suggests that the musician performed the first musical phrase with an expressive intention that seems to anticipate the second musical inflection point, far away, at the end of the second musical phrase. That would require a broader image of the musical structure, allowing for a previous and more consistent planning of the interpretation he is trying to accomplish. With the presence of the metronome, on the other hand, the musician tends to develop a more locally driven image while performing the piece, also emphasizing the first musical inflection point, at the end of the first phrase. The strong influence exerted by the metronome makes the head movements shorter in time and space, and also more correlated to the musical metric, probably inhibiting any expressive intention that transcends this metric.

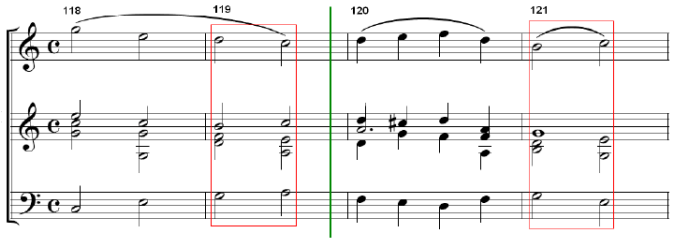

Fig. 4. Harmonic resolution progressions at the end of the first 2 phrases of Mozart's Quintet for Clarinet and Strings.

V. Conclusion

Short duration physical gestures were identified, based on a segmentation of the musician's head movements during musical performances. Correlations were also identified between these gestures and the musical structure, as well as between these gestures and the musician's different expressive intentions, induced by the chosen interpretation styles. Morphological and kinesthetic criteria were the basis for the motion segmentation used, but an approach more focused on the geometry of the trajectories, as well as the knowledge on human movement could provide broader results.

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