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THE RELATIONSHIP BETWEEN ANCILLARY GESTURES AND MUSICAL PHRASE ORGANIZATION: APPLICATION TO FLUTE PERFORMANCE

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The Relationship Between Ancillary Gestures and Musical Phrase Organization: application to flute performance

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Technique doesn't exist, the technique is something...
it's how to use your body in order to produce something what you want to do, and this is every moment changing.
So, because it's always changing, you can't consider it a technique.
It's an art of using the body!
Of course, you can see dancers have a technique, musicians have a technique, but it's our words to explain it, because in the end it's not technique. If it's a technique it's not good anymore.
So, I think we approach music and we see how can we be the instruments of that.
(Maria João Pires (MAES, 2013))

ABSTRACT

The process through which musical communication occurs varies broadly. Empirical researchers have shown evidence that performers consciously manipulate different acoustical parameters, with the goal of expressing their ideas to the audience and other musicians. The physical gestures produced by players during their performance are other aspects that have been observed by a broad group of researchers.

Although body movements are essential to the sound production of the instrument, gestures, in many cases, are closely related to the musicians' artistic intentions. The term ancillary gestures designates those gestures that are part of performance but are not intended to produce sound. Ancillary movements appear along with musical performance and, consequently, assume the intentionality of communication.

In this study, we observe musical phrase boundaries through the analysis of physical gestures. Considering that motion is associated with musical communication, our hypothesis is that gestures can express the way which performers understand musical structure and convey the direction of a musical phrase.

For this reason, we designed an experiment involving four professional flutists who were asked to play in three experimental conditions, four times each: (1) playing solo, (2) playing following a previous recording of the clarinet, (3) performing in duet with a recording of the bassoon. The motion and audio of flutists' performances were analyzed to evaluate the relationship between physical gestures and musical phrase organization.

The results point to a complex interrelationship between musicians' gestures and the manipulation of acoustical parameters through which performers express their interpretative intentions. This work also demonstrates that ancillary movements are not random, given that they are recurrent and stable in all experimental conditions.

The methodology presented in this study can be used in future works assuming ancillary gestures as a result of the process of musical thinking.

Key-words: Musical performance. Manipulation of acoustical parameters. Ancillary gestures. Non-verbal communication. Flute performance.

RESUMO

O processo no qual a comunicação musical ocorre varia amplamente. Pesquisas empíricas vêm apresentando evidências de que os músicos manipulam, conscientemente, diferentes parâmetros acústicos, objetivando expressar suas ideias musicais para os ouvintes e os outros músicos. O gesto físico produzido pelos performers, durante suas interpretações, vem sendo observado, com o propósito de analisar sua relação com a organização das ideias musicais.

Embora o movimento do corpo seja essencial para a produção de som, no instrumento musical, gestos, muitas vezes, possuem estreita relação com as intenções artísticas dos músicos. O termo "gesto auxiliar" caracteriza os gestos que fazem parte da performance mas, que não necessariamente produzem o som. Gestos aparecem ao longo da performance e, consequentemente, assumem a intenção de comunicar.

Neste estudo, analisamos as delimitações das frases musicais através do gesto físico. Considerando que o movimento está associado com a comunicação musical, a hipótese é que o gesto possa expressar a maneira na qual os músicos compreendem a estrutura de uma obra e como eles comunicam suas frases musicais.

Para este fim, desenvolvemos um experimento contando com quatro flautistas profissionais que foram convidados a executarem uma obra em três condições experimentais diferentes, quatro vezes em cada formação: (1) tocando solo; (2) seguindo a gravação, anteriormente coletada, de um clarinetista; (3) seguindo a gravação de um fagote. O movimento e o som das performances dos flautistas foram analisados com o objetivo de estudar uma possível relação entre o gesto físico e a organização das frases musicais.

Os resultados apontam para uma complexa inter-relação entre os gestos performados pelos músicos e os parâmetros acústicos manipulados por eles para expressar suas intenções musicais. Este trabalho mostra também que os gestos auxiliares não são aleatórios, uma vez que os mesmos são recorrentes e estáveis, em todas as condições experimentais.

A metodologia apresentada aqui também pode ser utilizada em futuros estudos de outras áreas do conhecimento, assim como nos estudos envolvendo a comunicacão musical e em trabalhos tendo a música como linguagem. Esperamos que este trabalho seja o primeiro passo para mais estudos que envolvam o gesto auxiliar como parte do processo de pensar musicalmente.

Palavras-chave: Performance musical. Manipulação de parâmetros acústicos. Gestos auxiliares. Comunicação não verbal. Performance de flauta.

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1 INTRODUCTION

Musical communication has been observed by a broad group of researchers focusing on the manipulation of sound (GABRIELSSON, 2003; JUSLIN, 1997; JUSLIN, 2000) and physical gestures produced by musicians (WANDERLEY et al., 2005; CARAMIAUX; WANDERLEY; BEVILACQUA, 2012; TEIXEIRA et al., 2015; CADOZ; WANDERLEY, 2000), during their performance. Studies have demonstrated that body movements, other than being essential to sound production on the instrument, in many cases, are also closely related to the performers' artistic intentions (WANDERLEY, 2002).

According to Marcelo Wanderley and Eduardo Miranda (2006), the study of gesture in music is an important area of research that raises many issues about perception, performance, and emotional communication. The authors point out that movements are part of performance but not necessarily produce sound. These gestures have been considered essential to the instrumentalist's performance, and some of them are stable and reproducible, even after extended periods of time. Therefore, the repeatable movement patterns seem to be intimately connected to the structure of the music being performed. It should be regarded that these movements might also have a communicative function in enhancing the perceivers' experience of the sound's phrasing (JENSENIUS et al., 2010).

This study involves instrumental ensemble performance, focusing on how flutists adjust their sound and gestures during different duet situations. By observing modifications in the musical phrases and physical gestures which are communicated by musicians during sound production in performance, a strategy to understand the relationship between physical gestures and musical gestures can become clear. Considering that gestures in speakers come about as a by-product of changes in speech (GOLDIN-MEADOW, 2005), we believe that this work can be useful to understanding the organization of musical ideas through the physical gestures.

The data collection involved four flutists playing solos and subsequently playing along to recordings done by other musicians, namely a clarinetist and a bassoonist. In the first step of the analysis, we observed the video of the flutists' performance and examined the commonalities and idiosyncrasies among them. In the second part, the movement analysis was expanded upon using detailed, three dimensional motion analysis.

Our work proposes to compare flute players' performances in different ensemble conditions, focusing on the way in which flutists interpret the musical structure in each of the imposed situations. In instrumental ensemble performance, musicians need to adjust various acoustic parameters to achieve the intended interpretation of the group (GOODMAN, 2002). These adjustments and influences are mutual, given that each one has an impact on and can adapt to one another. Expecting a mutual influence, by simulating the ensemble performance situation

in which subjects follow the partner's recording, we can facilitate the analysis of the influence exerted by the instrumentalists' audio recordings only and can discard the possible impact made by the performance of the flutists. In other words, flutists were only influenced by the recordings.

The primary hypothesis is that different conditions (musicians playing solo or following other's perceptions of the same piece) change the musical discourse, and consequently these new musical phrases can be reflected in these physical gestures. Mota and colleagues (2014) suggest that musicians have a "musical signature," observed within acoustical parameters and consequently, a "gestural signature" related to the manipulation of their sound.

Gestures tend to be stable, and are not random, carrying a significant relationship with the players expressing their artistic interpretation, and consequently the musicians' individualities. The results of motion and audio analysis of flutists' performances will be studied to assess our assumption.

The experiment designed in this study and data collection procedure, as well as the methods developed for the motion and audio analysis, will be explained in the text. The thesis' structure involves five chapters, besides this introduction and a general conclusion, including the future scope of the study.

2 MUSICAL COMMUNICATION

According to Margulis (2014), music is a vital human function, and essential to brain, emotional, and social activity. Music and language, considering human communication, occupy a similar level of importance and meaning to human beings. Kofi Agawu points to the importance of music, and the occurrence of language, music, and religion in all human societies.

> Setting aside for now evidence that nonhumans sometimes engage in these activities, we can state that in all known societies, humans make music, communicate through spoken language, and maintain prescribed sets of beliefs and practices. There are, of course, languages in which the word *music* is not found, but the presence in such societies of a species of rhythmic and tonal behavior that we may characterize as music making is rarely in serious contention. (AGAWU, 2009, p.21)

However, cognitive science only considers language as important to studying the human mind, and only just recently has music received considerable attention.

Musical communication is a process that involves musicians expressing and communicating ideas to an audience or other musicians. Performance planning and practicing include adjusting acoustic parameters such as note durations, intensity, pitch, timbre, and note articulation. These modifications are methods or strategies with which musicians convey their musical intentions (GABRIELSSON, 2003; JUSLIN, 1997; JUSLIN, 2000). By changing parameters of sound, a performer can completely alter the performance of a musical piece through the way it is expressed (FRIBERG; BATTEL, 2002).

The process in which musical communication occurs and the strategies within this process, vary broadly. A pre-existing condition to ensure a convincing musical performance is the way in which the structure of music is expressed. Recent works have focused on methods that describe the expressive intentions in music performance, by analyzing variations of sound (REPP, 1992; FRIBERG; BATTEL, 2002), given that researchers have pointed out that musicians perform small deviations in note durations, articulations, timbre and intensity to convey their musical intentions (GABRIELSSON, 2003; JUSLIN, 1997; JUSLIN, 2000).

The term "communication" suggests that speech and music have many properties in common. According to Dahl and Friber (2007), it is probable that this similar idea can be applied to musical communication as well. Communication in other areas such as linguistics explores the speech and gestures produced by speakers during a conversation. Researchers (GOLDIN-MEADOW, 2005; MCNEILL, 2005) suggest that ignoring gestures during a dialogue is ignoring part of the communication.

Studies in musical performance are a broad research question based on experience and methods from several domains. A strategy is to examine various aspects of artistic planning and performance by musicians at different skill levels and with dissimilar cognitive resources beyond

the analysis of movements. The body movements executed by the performers while playing have been studied by several researchers (WANDERLEY, 2002; TEIXEIRA et al., 2015) and their findings indicate that physical gestures are part of musical performance.

Although body movements are essential to the sound production of the instrument, gestures, in many cases, are closely related to the musicians' artistic intentions (WANDERLEY, 2002) and these movements have been considered essential to the instrumentalist's performance.

In 1988, Delalande studied the musical and physical gestures during Glenn Gould's performances and detailed an order for these. The instrumental gestures themselves were analyzed a priori in three levels, ranging from purely functional to purely symbolic. Effective gestures (1) are those that mechanically produce the sound. Accompanist gestures (2) are those that musicians associate with essential movements (instrumental gestures) but apparently are less necessary, such as movements of the shoulders or knees, or breathing for a pianist. Finally, figurative gestures (3) are those recognized by the audience.

Delalande (1988) explained that the accompanist gestures are probably as helpful to the mind as to the actual production of sound. Cadoz and Wanderley (2000) compared several definitions and pointed out the specificity of the concept *gesture* in the musical field as related to communication. They also lead to different representations of gestures performed by musicians while playing and proposed a classification, such as instrumental gestures and ancillary gestures.

Instrumental gestures are produced during a physical interaction and are a similar mode of communication to empty-handed gestures. The authors suggested three types of hand actions or hand gesture functions: ergotic (1), involving the energy's transfer between the hand and the object; epistemic (2), including of the capacity of muscle and touch; semiotic (3), affecting the meaning or communicative intent. On the other hand ancillary gestures, although not produced intentionally to generate or modulate sound, are present and part of expert performances.

Having said that, the terms "accompanist gestures" and "ancillary gestures" have been used to classify the actions produced by musicians during a musical performance but that are not producing sound. However, Jane Davidson (1993) used the name "expressive movements", and Sofia Dahl and Anders Friberg considered the expression "body language" to denote the same idea. It is interesting to note that the ancillary gestures are usually present in professional performers (WANDERLEY; DEPALLE; WARUSFEL, 1999), and these gestures appear as non-lexical elements of communication during speech (MCNEILL, 2005).

By analyzing the relation of physical movements and sound's manipulation during a musical performance by listeners, Jane Davidson (1993) was able to point out that the audience can recognize the musician's expressiveness in both modalities: acoustical and visual. The most important result is that participants considered the image as important as the sound.

Studies in psycholinguistics have shown that gestures and hand movements are directly tied to speech; consequently, they carry on the intentionality of expression. According to McNeill

(1992) gestures and speech are tightly connected with the conversation in timing, meaning, and function.

The concept “gesture” was defined by McNeill (1992) and replaced the previous term “gesticulation” used by Adam Kendon (1980). Gesticulation can be proclaimed as a conventionalized sign, such as thumbs-up for “OK" and occurs with or without speech. Also, as co-articulation, it signifies a fusion of micro-gestures into more super-ordinate gestures. Gestures during the musical performance also appear as a gesticulation or common sign in the musical ideas’ organization. The physical gesture can emerge as a co-articulation within a larger phrasing or to express a single musical idea.

Goldin-Meadow (2005) explains that “although speakers may not be completely aware of having produced hand movements, they are very aware of having spoken. Their gestures are in the service of communication and, in this sense, are deliberated." (GOLDIN-MEADOW, 2005, p.4). The author demonstrates that gestures are produced as part of an intentional communicative act and are formed during speaking as a participation in communication.

Although the gestures appear to serve an important function for audiences (communication), the mechanism by which we produce do not necessarily involve communication and the listener. Susan Goldin-Meadow (2005) points out that people provide gestures independently of any listener’s presence, similarly to speakers gesturing while on the telephone with no visual contact with the audience. Likewise, instrumentalists still move while practicing in their private room. According to the researcher, an alternative possibility is that we produce gestures as part of the process of thinking.

Studies involving human communication compare gestures and speech, intending to comprehend the relationship between movements and talking, and taking into consideration the fact that speakers can modify the structure and content of their speech and that those alterations can cause changes in gestures.

This approach to gestures is of interest to us, given that, in musical performance, the instrumentalists produce similar motion as part of a communicative act. Some studies have shown that ancillary gestures have a relationship with the metrical structure, grouping of phrasing (WANDERLEY et al., 2005), and/or key musical moments (TEIXEIRA et al., 2015).

Wanderley (2002) showed evidence of a correlation among gestures at specific points in a score when comparing several performances of the same piece by a musician. This finding suggests that ancillary gestures are not produced randomly nor just as a visual effect, but are an indispensable part of the interpretation process. According to a study involving the Laban Technique (CHAGNON; CAMPBELL; WANDERLEY, 2005), performers movements emerge from their abilities and acquired skills, to convey expressions, intentions, and emotions. Musicians are able to eventually reduce their body movements while playing, but never eliminate them completely (WANDERLEY, 2002).

Marc Leman (2008) explains the concept of music "embodiment" in which the human body is a mediator between the musical mind and the physical environment, and the gestures can be the way in which this body extends itself in space and time. According to Leman (2008), the gestures are part of synchronization and entrainment of the body and the meaning of the emotional engagement as well as deliberate actions.

Comparing the artistic research and studies that involve gestures and speech, we perceive a similarity between them, mainly how gestures embody discourse information. In a recent study (MAES et al., 2014), researchers proposed a theoretical frame that obtains the forms in which the human motor practice and its effects can reciprocally affect the perception of music. The authors explained that it is not about how the body resonates with the music, but how predicted sensory outcomes of planned or performed actions can be projected onto the learned music. The integration of action and perception in this internal pattern is defined as a result of associative learning processes.

The schema of our experiment (figure 1) involves the flutists playing solo and, consequently, expressing their musical phrases. These actions were based on flute player's perception of the score, resulting in a particular action. In the next step, the flutists were asked to play with the recordings of other instrumentalists, leading to various forms of adjustment in a duet situation. This resulted in a change of perception and therefore a new action.

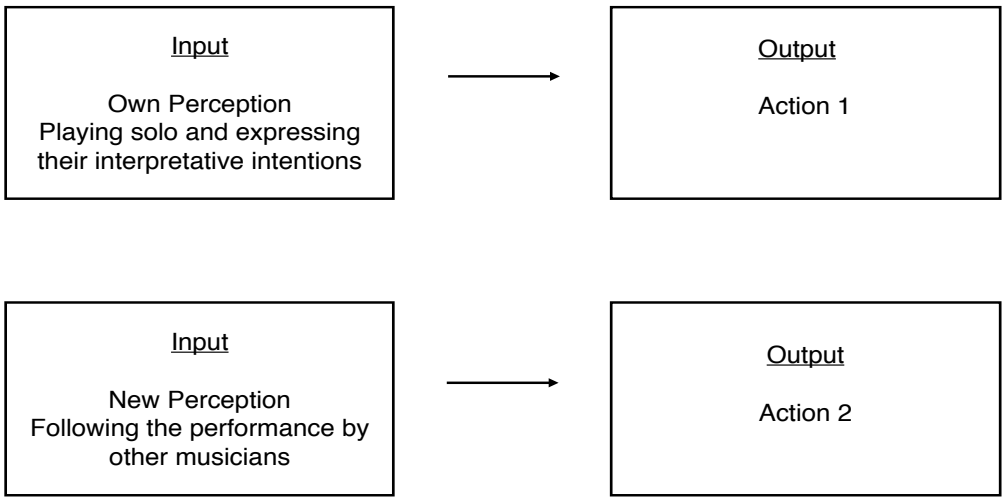

Figure 1 – Schematic diagram illustrating the experiment's design. Firstly, the flutists play solo expressing their interpretative intentions of musical phrases resulting in Action 1. Secondly, flute players were asked to follow other different interpretation in performing Action 2.

Our primary objective is to find out if the movement and the audio produced by these flutists has a relationship. The second objective is to research this association and evaluate the possible changes and adaptations in a different musical organizations with which flutists were presented. For these reasons, our experiment involves ensemble performance: a practice which requires musicians to adjust acoustic parameters and the grouping of notes to achieve the intended interpretation of the group. Regarding the understanding through actions and the perception of each one in terms of the same musical piece, gesture production involves the process of thinking and how the musicians express the form and content in their musical organization.

3 METHODS

3.1 Experimental Design

Six professional musicians (four flutists, one clarinetist, and one bassoonist) from Brazil were invited to participate in the research. All of them had at least 30 years of musical training. Various constraints, the level of difficulty, and demands for a certain level of excellence usually create a need for more anticipation and more ancillary gestures from the performer, especially for beginners. Experienced performers acquire tricks throughout the years to achieve high goals without the need for spurious gestures.

The musicians were asked to play a particular excerpt: the second movement of Wind Quartet No. 2, in G major by Gioachino Rossini (Figure 2). Although the selected piece was composed for four musicians, we chose just three instruments (flute, clarinet and bassoon) and organized them in duets.

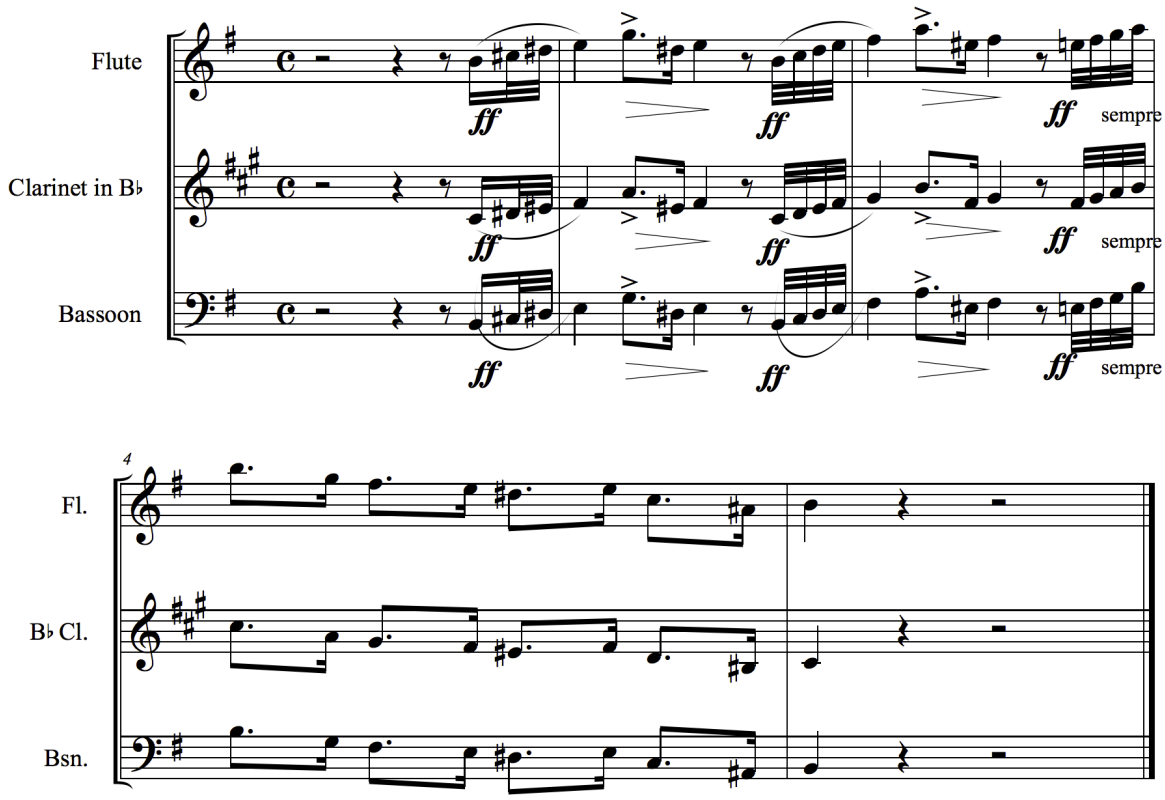

Figure 2 – Second movement of Wind Quartet No. 2, in G major by Gioachino Rossini. The example above shows only the three instruments in unison.

The piece, in which wind instruments play in unison, was chosen because it presents a real performance situation that requires adaptation at every musical note and phrase. When musicians play together in unison (same pitch or an octave apart), they immediately need to adjust various acoustical parameters with ensemble partners. Manipulations may also occur in the way they group notes in musical phrases. Thus, one way to study the player's musical intentions is with these musical groupings.

Additionally, musicians were asked to play another piece under different musical conditions, *stretto*, composed by Heitor Villa-lobos. The objective is to include other possibilities, in the case of comparison with Rossini's piece. However, the complete analysis will only be on the piece in *unison*.

The experiment was realized in two sections. In the first part, each instrumentalist played the excerpt solo with his/her interpretative intention, four times. In the next section, the flutists were asked to play the musical passage, four times each, with a headphone in one ear, while the clarinet and the bassoon were recorded in the first session. The clarinetist and the bassoonist were asked to indicate the preferred recordings to be followed by the flutist's in the second session. For reference, a metronome produced a steady tempo at 67 bpm (beats per minute), before each take.

The only instruction given was to accompany both instruments in the best way they could. A total of 48 takes were recorded: 32 takes in duet, and 16 solo takes. The use of the headphone was necessary to be able to record each instrument separately.

In a previous study (SANTOS; OLIVEIRA; LOUREIRO, 2014) we simulated ensemble performance by asking flutists to follow recordings of different instruments played through headphones in one ear. The paper aimed to discuss timbre modification, due to coupling interpretation of ensemble performance and investigate the timbre's perception through headphone in one ear. We compared the sound quality of solo performances of orchestral excerpts played by professional flutists, with their own performances when following the clarinet and bassoon playing the same excerpt in unison. During this study, timbre was represented by two of the descriptors discussed by McAdams and colleagues (MCADAMS et al., 1995; MCADAMS, 1999), the logarithm of attack time and spectral centroid. We were able to observe that flute players tend to modify their timbre when following clarinet and bassoon with different tendencies for each instrument. In other words, flutists perceived the modification of the timbre manipulated by different musicians through headphones in one ear.

Another significant point was restricted to just one stimulus for all flute players with the assumption that, if the clarinetist and/or bassoonist had played in the ensemble with all flutists, they could change their interpretation for each duet. This is one possible way to unveil specific aspects related to the expressive intentions of recordings during the analysis and the comparison among flutists.

When playing solo in the first session, the musicians played as if in a real practice or rehearsal situation by themselves, in which she/he chose to express their interpretative intentions. Whereas, in the second session, the performers were required to adjust themselves to the way the ensemble partner interprets the score.

The assumptions behind these experimental conditions demand of musicians constant adjustment while they were expected to follow different perceptions of the musical piece. The process of perceiving and acting provides acoustical and physical manipulation by musicians in different performances, and we intend to analyze these changes.

3.2 Data Acquisition

The data was collected at the laboratory of CEGeME - Center for Study on Musical Gesture and Expression, at the School of Music of the Federal University of Minas Gerais. The audio was captured by an omnidirectional microphone (M-Audio Solaris) at a sampling rate of 44.1 kHz, using an M-audio Firewire 1814 interface. The microphone was located approximately 1 to 1.5 - meter, relative distance, from the source, given that flutists could move during their performances. In the second session, the previously recorded clarinet and bassoon tracks were played back through an Audio-Technica ATH-M50 headphone in only one ear, leaving the other ear free for the flutist to listen to his/her sound, creating a semi-closed situation. The software program Audacity was used for recording and playback. All musicians used their own instruments during the performances.

Motion tracking was done with the NDI Optotrak Certus motion capture device, at a sampling rate of 100 frames per second. Markers were positioned on the musicians' bodies and instruments. The Optotrack cameras were placed vertically, three meters away from the musicians. Two rigid bodies were used, one on the flutists' head and another on the flute. Figure 3 shows the data acquisition setting with the adopted coordinate system: x-axis is the lateral displacement, y-axis is the height, and z-axis is the depth.

The collected data by Optotrack was analyzed into Matlab arrays and, when necessary, coordinate transformations were implemented. Interpolation was applied to the data in order to estimate possible occluded markers during performances. Additionally, we used the MoCap Toolbox plugin for visualizing data parsing (BURGER; TOIVIAINEN, 2013). The MoCap Toolbox is a set of functions written in Matlab dedicated to the analysis and visualization of motion capture data. We used a clapper-board during the experiment in order to synchronize data sources, sound and movement.

In this study, we also used video and sound recordings - obtained using the Zoom Q2HD Handy HD Video Recorder - as a complementary tool to analyze ancillary movement. The aim of this work is to investigate the physical gestures executed by the musicians during a musical performance and to examine the possible gestural patterns related to their artistic intentions and

the musical structure.

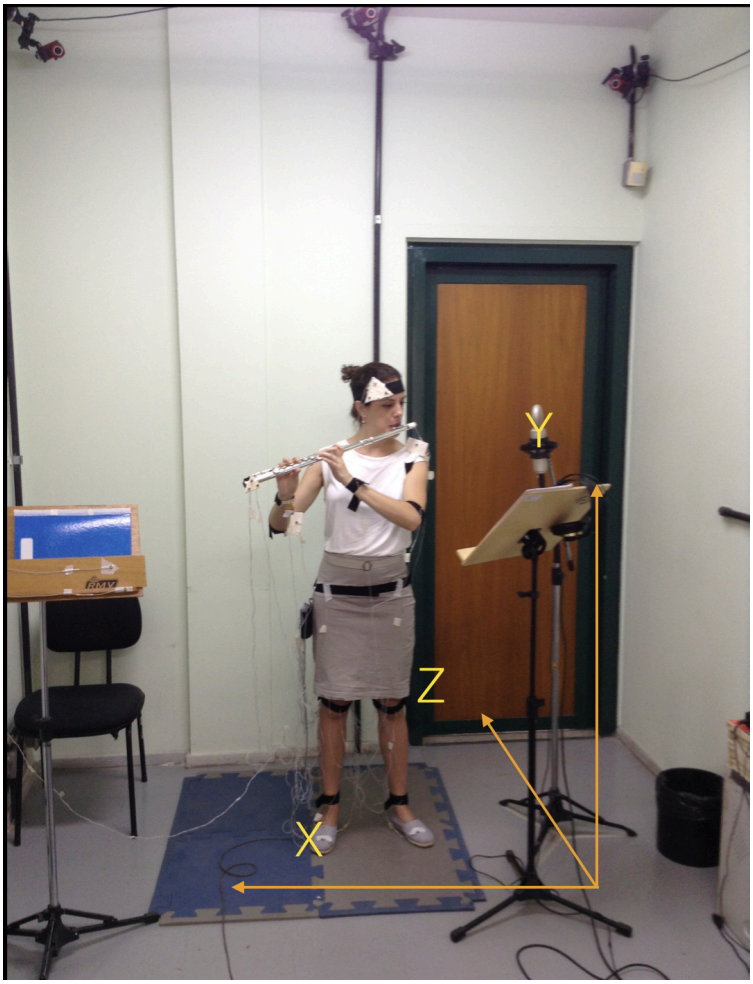

Figure 3 – Data acquisition setting, from the motion capture tracker viewpoint in 3D (x, y, z). The participant signed a consent form allowing the reproduction of this picture.

3.3 Self-Report

The flutists also were asked to participate in a listening test in which each musician selected the musical phrases while listening to the recorded takes of all flutists, including her/himself, under the experimental conditions. The goal of this test was to identify the musical intentions of all flute players using the flutists' perceptions. Musicians segmented how they perceived the musical phrase organization, delimiting the musical motifs or phrases through listening.

In addition, the flutists were submitted to a semistructured interview [1], explaining how they identified the organization of the musical ideas during the listening test, and discoursed about grouping their phrases while playing the excerpt. Finally, we presented the research hypothesis to flute players, in which the physical gesture is concerned with the grouping of musical motifs to musicians. The following questions were asked:

1. How did you organize your musical ideas? What is your idea about grouping the notes in this excerpt?

2. Which aspects did you consider to separate the musical phrase when you listened to the recorded takes?

3. Do you believe that movements are related to musical ideas?

Responses indicated that performers are aware of their artistic intentions and the way in which they organized the piece played. Given that, they identified the boundaries of phrases performed and consequently, the relationship with their intentions. The flutists revealed some aspects which they considered to segment the phrases while listening to it, such as, differences in sound's energy and articulation. According to Friberg and Battel (2002), there are cues to identify idea boundaries such as variations in timing, decreasing of sound energy, bending of timbre, the strength of notes, and in some cases, changes in the articulation. In fact, these manipulations in the sound broadly change an interpretation. However, it is not possible to define one rule to determine the limits of an idea, but there can be strategies used by musicians to identify the limitation of musical phrases.

Concerning the last question, some flutists were surprised when identified the relationship between physical gestures and the way how they organized their musical phrases. Considering that they are aware of the manipulation of their sound to express their intentions, but not entirely conscious about the possible relationship their movements have with their musical phrase organization. One performer stated: "I'm surprised, I'm not aware of performing these gestures." Furthermore, flutists agreed that movements affect their performance, and often they use the gestures to express musical conduction and to communicate with the audience or other musicians.

[1] According to the authors Christian Laville and Jean Dione, which consisted of questions offered verbally in a planned order. Nonetheless, the interviewer can add and clarify the questions.(LAVILLE; DIONNE, 1999)

Though musicians are knowledgeable about the production of ancillary movements while playing, they do not seem cognizant of the regularity and details of these gestures. Moreover, players do not give the impression of being mindful of gestures that can be related to their organization of musical ideas.

4 ANALYSIS METHODOLOGY

Musicians are aware of normative aspects of musical structure and they are subordinated to them. However, during musical communication, performers express their individual choices. Our goal in this study is to observe both aspects, individuality and commonality, that may emerge in ensemble musical performance, analyzing the sound and the gestures performed. Therefore, in order to compare the different musical performance situations, we conducted an analysis in both modalities, sound and motion.

In this chapter, we will report both analysis methodologies: acoustical and gestural. During the individual analysis of flutists and consequently, the comparison among them, we will use different strategies which will be explained in detail.

4.1 Acoustical analysis methodology

Firstly, we segment the recorded audio into musical notes. We used a combination of pitch and amplitude values to detect note onset and offset, end of attack, and beginning of release. This process was accomplished automatically with the use of EXPAN, a tool developed at CEGeME for musical expressiveness analysis (CAMPOLINA; LOUREIRO; MOTA, 2009).

A Sonic Visualizer plugin (CANNAM; LANDONE; SANDLER, 2010) developed within the EXPAN toolbox was also used for inspection and adjustment of the segmentation parameters. After that, the audio vector of each performance was processed, and acoustical descriptors of each note were obtained.

The current investigation regarding communication of musical structure in performance focuses on the analysis of variation in acoustical descriptors. Loureiro (2006) points to methodology approaches exploring the musical expressiveness due to the sound's information and identifying descriptors capable of analyzing the artistic content of a musical performance. The process of performance planning and execution involves the manipulation of sound with which the musicians can emphasize or minimize various aspects of a piece.

Previous empirical studies have suggested evidence that performers manipulate different acoustical parameters such as note durations, intensity, pitch, timbre, and note articulation, aiming at expressing and/or communicating their ideas to the other musicians or the audience (GABRIELSSON, 2003; DAVIDSON; KING, 2004). Moreover, the performance planning also includes decision making to group notes in phrases, emphasize harmonic features, and/or highlight rhythmic units. Both principles are not necessarily independent, and these changes influence how the structure is intentionally transmitted. For these reasons, the auditory perception and the self-report made by the musicians were considered.

4.1.1 Articulation

Nancy Toff (1996) explains that the articulation is a technique of connecting musical tones, determining the relationships between single notes and the surrounding notes. According to the author, the articulation is similar to what we think of as phrasing and not just tonguing. The *Legato*, on the flute, is produced by a single blow sustaining the air flow during the transition of tones, without using the tongue. In other words, regularity and continuity of sound must be obtained by a blending of constant breath, support and flexible embouchure synchronized with finger motion.

According to Maestre and Gómez (2005), the *Legato* descriptor indicates how clearly two notes are separated. The authors explain that when there is no silence between two consecutive notes, we can consider that a note transition segment begins at the first note's release and ends at the attack of the following one. Both the energy envelope and the fundamental frequency contour during transitions are studied to extract this descriptor's information.

Figure 4 shows the ideal *legato* with the dashed line from the beginning of the release of the first note to the end of following note's attack, and the areas used to calculate the *legato index*. In this work, we use the *legato index* to represent the quality of legato and to analyze the tendency to segment notes and consequently the fragmentation of musical ideas.

Campolina and colleagues (2009) consider the descriptor, *legato index*, the measurement of the quality of this transition through the comparison to an ideal legato without any decrease of energy, as shown in figure 4. This comparison is calculated by means of the area A1 (between the traced line and the energy curve) and the whole area A1 + A2, as presented by equation 1, where: L is the ideal legato; EA is the end of attack; BR is the beginning of release; RMS energy is the root mean square of sound's energy; t is the time; A represents both areas 1 and 2; and i is a note and i+1 is a consecutive note.

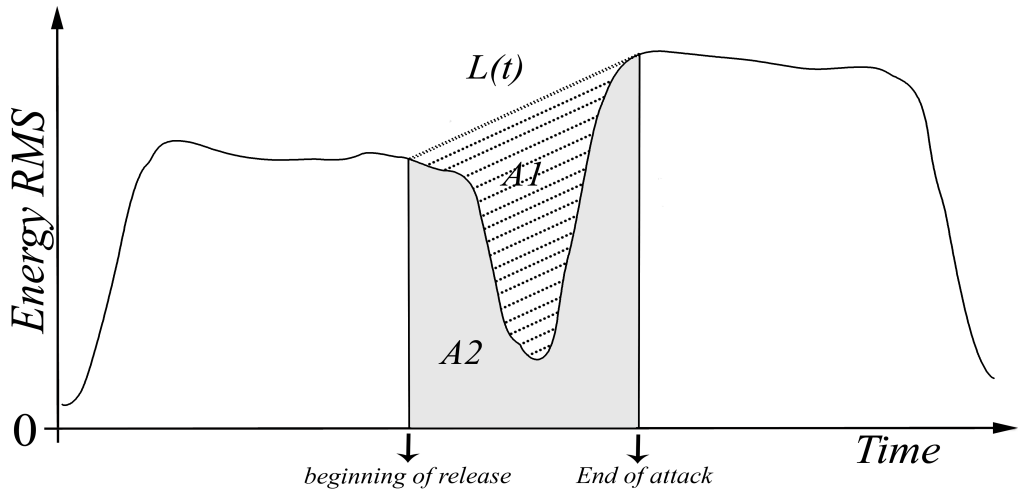

Figure 4 – Areas used to calculate the *Legato index*. Where energy RMS is the energy envelope; L is the ideal legato; A represents the different areas, such as A1 and A2.

$$LI(i) = 1 - \left[\frac{A_1}{A_1 + A_2}\right] = 1 - \left[\frac{\sum_{t=BR(i)}^{EA(i+1)} |L(t) - RMS(t)|}{\sum_{t=BR}^{EA(i+1)} L(t)}\right] \tag{1}$$

Another descriptor is the sustain index of sound which measures the duration of a single note and the relation with the following one. The descriptor's measurement is based on the note onsets and offsets extraction from the audio signal, estimated as the ratio between note duration (ND) and the Inter-Onset-Interval (IOI), as shown in Equation 2. We will use this descriptor to demonstrate when flutists expanded the notes and consequently the boundary of the phrases. The observation of this sound descriptor can show the intentional manipulation of note duration by the flutists (figure 5).

$$\frac{t^i_{offset} - t^i_{onset}}{t^{i+1}_{onset} - t^i_{onset}} \tag{2}$$

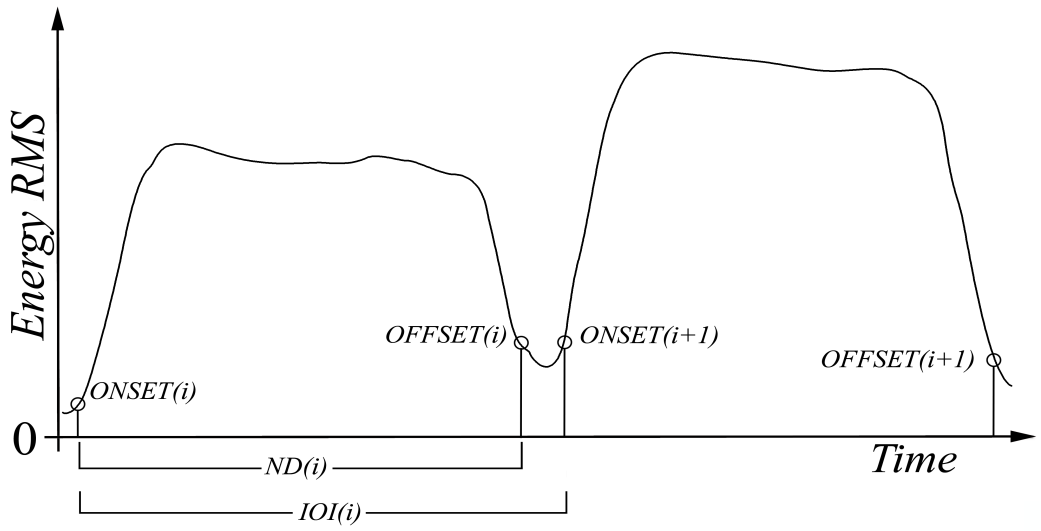

Figure 5 – Parameters used to calculate the sustain index of sound. Where energy RMS is the energy envelope; DR is note duration; IOI is the inter-onset-interval.

4.1.2 Timing

Sundberg (2000) considers the two most important principles for communicating musical structure: (1) differentiation of pitch and duration; (2) grouping of notes in phrasing, metrical units, or harmonic areas. Furthermore, the author explains that the perception is enhanced by increasing the difference between categories, such as stretching notes or playing short notes even shorter (duration contrast), beyond the variation of the sound's energy as changing dynamics of the sound.

According to Keller (2014), the timing deviation can have horizontal and vertical relations between sounds. The vertical timing variations affect the degree of synchronization of sound in separate parts within the ensemble texture. Meanwhile, the horizontal relations concern the timing of successive sounds within each voice or instrumental part. Both aspects work to modify the harmonic and melodic music features.

A standard mode of horizontal deviation requires intentionally varying the length of metric inter-beat intervals to produce systematic modulations in local tempo (GABRIELSSON, 2003). Todd (1985) suggested that often in the phrasing endings occur a decrease in the *tempo*, reflecting hierarchical relations and the boundaries of musical ideas.

In 1938, Seashore pointed that horizontal timing variations are exceptionally consistent across performances of a piece by the same musician. Repp (1992) corroborated and added that musicians who interpret music quite differently might produce similar patterns of timing and

dynamics.

During the ensemble performance, the vertical deviation directly affects the temporal relationship between sounds. Playing simultaneous notes is not only impossible but also undesirable in human music making. As pointed out by Rasch (1988), not synchronizing notes should be considered one of the substantial interpretations in the performance of music. Vertical timing deviations have multiple determinants apart from perceptual and motor limitations. However, it also can involve the musician's choice to stretch or to shorten some note generating tension or release as part of the musical interpretation. Other factors such as tempo, musical structure, style, and leader–follower relations, may affect the vertical timing deviations. That said, the variation of timing can be a useful method to compare different expressive intentions of musicians, and it will be discussed in chapters 5 and 6.

In this study, the timing has been analyzed through the descriptor IOI (Inter-Onsets-Intervals). The variation of the length of metric inter-beat intervals to produce systematic modulations in local tempo or timing is measured by the change of Inter-Onsets-Intervals (IOI). The inter-onset-intervals are based on only the note onsets obtained from the audio signals. In this study, the IOI's are normalized to the quarter-note. Figure 6 represents the manipulation of timing. The variation from this line indicates a note duration manipulation by the instrumentalists, which, above the line shows a longer note and below the line means a shorter note.

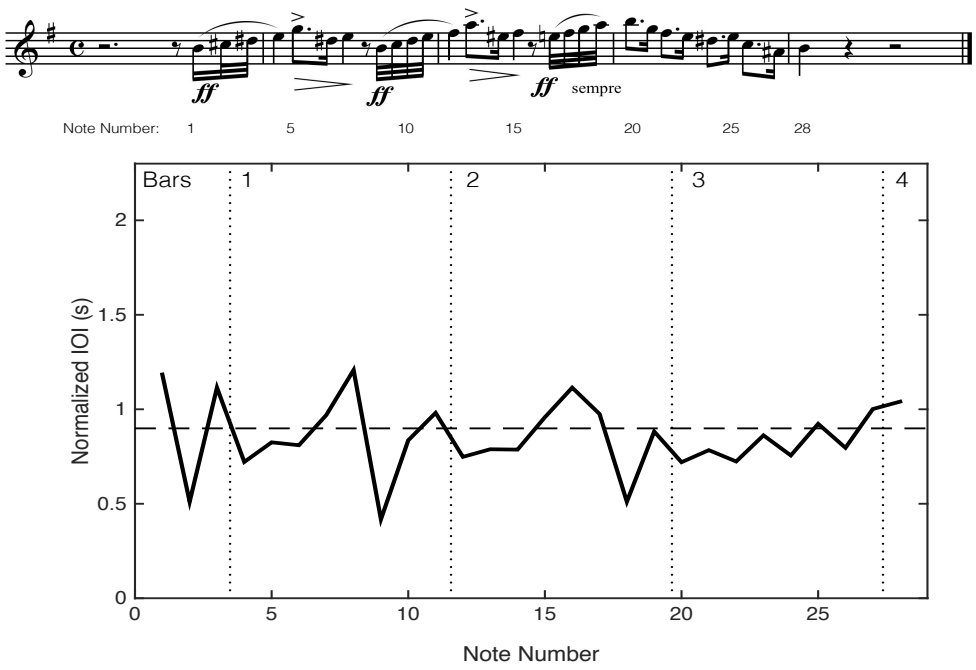

Figure 6 – Note inter-onset intervals for the performances of Rossini's excerpt by the flutist 1. The IOI was normalized to the quarter-note. The horizontal dashed line exhibits the canonical values.

4.2 Movement analysis methodology

Our movement analysis is based on two parts. First, we perform gestural analysis based on observation of video recordings, and secondly, using information obtained from a high-accuracy three-dimensional optical movement tracker. The visual analysis of video recordings proposes to perceive and to identify flute players' gestural features, for observers without formal training in motion, using the Laban-Bartenieff system. The movement analysis tracker data aims to expand it with a detailed evaluation of the action.

4.2.1 Visual analysis of video recordings

The Laban-Bartenieff Movement Fundamentals was created by Rudolph Laban (1879 – 1958) and Irmgard Bartenieff (1900 – 1981) and consists of a framework for describing, recording, and developing movement. Although intense training is needed to understand the system, an adequate knowledge of Laban-Bartenieff Movement Fundamentals can be learned and used to observe movements.

Note that in the study of human behavior using methods like Laban-Bartenieff Movement Analysis, the observer plays a significant role in interpreting the subject's motion. The researcher brings in their set of biases based on their experience and expertise. Thus, if any one of these factors changes, the resulting observations may change as well. The choice of this procedure was the first step to recognizing possible patterns or commonalities between flutists before expanding it with a detailed evaluation of the movement tracker data.

Laban-Bartenieff Movement Fundamentals describes movement through the four inter-related categories of Space, Effort, Shape, and Body. However, we focus on a simple understanding of concepts to one particular class: Shape. The shape is connected with the body attitude in space. In other words, the shape is the gesture a person's body makes in space. That said, shaping qualities determine not only particular motor task, but also the person's mental intent, and can be extremely useful for observing musicians.

Figure 7 shows a flutist playing the selected musical passage. The plots were created through movement tracker data. Note that the mirror image makes possible a visualization of flute's trajectory. We will expand on the details about this analysis in the next chapter.

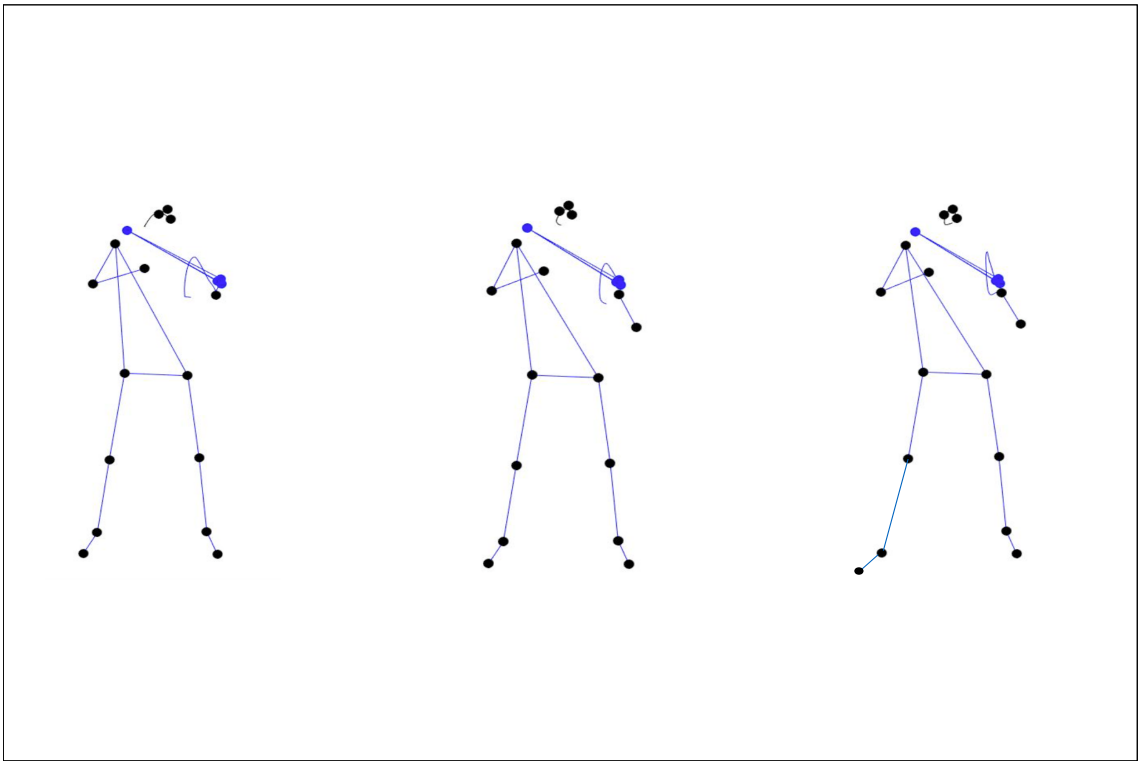

Figure 7 – The mirror images of a flutist playing a selected musical passage, where the flute's trajectories are the blue curve in three distinct parts of the performance.

4.2.2 Movement Segmentation

Previous studies have shown the clarinet bell movement has been the object of analysis (WANDERLEY, 2002; WANDERLEY et al., 2005; CARAMIAUX; WANDERLEY; BEVILACQUA, 2012; TEIXEIRA et al., 2015) and the authors have considered that the instrument's motion can be a significant indicator of artistic movements made by the players. Teixeira and colleagues (TEIXEIRA et al., 2015) explained the movement of the clarinet bell relative to a static reference: the origin of the Cartesian coordinate system. The authors explained that the static reference is located in the centre of the Optotrak. Consequently, the instrument bell movement can be regarded as a general sign of the clarinetists' movements.

In this study, we analyze the relative motion of the flute. Considering marker in the headjoint and footjoint, representing several actions performed by flutists. An important part of the flute is located in the headjoint, the embouchure plate or lip plate, where players position their lips, while footjoint is another extremity of the instrument.

The estimation of the relative movement of the flute: subtracting the marker's 3D positioned on the footjoint of the instrument and the marker's 3D located on the headjoint. Although we measure different angles of the flute in the space, we chose to represent the instrument's

position, given that the trajectory can be more intuitive to interpret than spherical coordinates. Although the flutists adjust their lips and chin to change the pitch and to maintain intonation the flute's motion is constant in this spherical coordinates (radius, horizontal position), given that the flute is a rigid body and consequently both extremities have the same movement.

Given that musical audio segmentation is facilitated by the onset and offset detection, there is no straight forward method for segmenting movement is available. Teixeira et al. (2015) suggest that the tangential velocity and local minima can be significant in the process to the segmentation of this data. The authors explain that the procedure uses the local minima as a basis for the movement segmentation, assuming that these particular points correspond to inflection points of the musician's movement. Therefore, the movement sessions will be between successive local minima in the tangential velocity curve (Figure 8).

The procedure consists in the estimation of flute's relative motion as a first step. Afterward, the Euclidian distance was measured between 2 subsequent spatial positions. Finally, estimating the tangential velocity, we used a low-pass filtering for smoothing. This process aimed to define viable similarities among the gestures and potential association of gestural features. The gestures involve one or more movement segments grouped. In this work, we arranged the movement sections through the association with onset notes in seconds. This association was performed to consider the local minima before the onset notes, and consequently, we can observe the preparation of the physical gesture. The beginning of notes which performed the grouping was defined by musical analysis and the analysis of musical intention of each flutist. It will be described in details upcoming.

Teixeira and colleagues (2010) confirmed that the tangential velocity is a particular unidimensional parameter which apprehends essential information from the musician's movements. However, a gesture can be constituted by one or more segments represented by local minima in the tangential velocity curve.

To analyze the relationship between the musical gestures and physical gestures, a connection between local minima in the tangential velocity curve and note onsets will be investigated. Several studies have pointed to movement recurrence in determined musical parts (WANDERLEY et al., 2005; CARAMIAUX; WANDERLEY; BEVILACQUA, 2012; TEIXEIRA et al., 2015), considering that ancillary gestures are related to musicians' expressive intentions, and they are expected to be recurrent over consecutive performances.

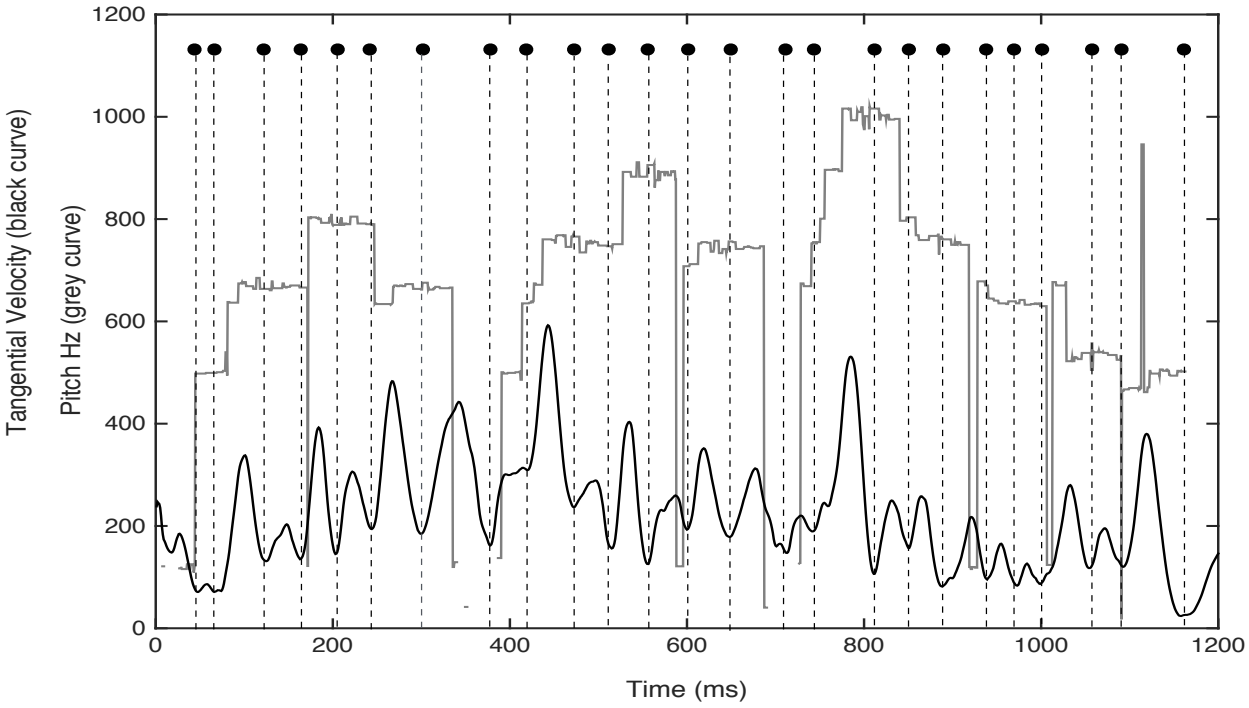

Figure 8 – Movement segmentation method: grey curve shows the pitch (Hz), and the black curve shows the tangential velocity of flute [mm/s]. The vertical black dashed lines illustrate the motion segments.

Rolf Godoy (2010) suggests that the continuous stream components and temporal aspects such as sound, need to be considered during the segmentation in the research that involves the idea of perception-action interaction in human activity. The author proposes segmenting the stream of sound into chunks to determine the sonic events and the gestures that correspond to these acoustic parts. This approach offers a definition of the gesture units.

Godoy (2013) explains that the chunks are based on the perception of musical sound related with body movement. The term "chunk" not only means a segmentation or method of analysis but it also becomes more stable in our minds “to something that does not exist at the timescale of continuous sensory streams.” (GODOY, 2013, p.368).

Considering that the constant stream of musical sound is amalgamated, the researcher seeks goal-direction in body motion or sound to segment the chunks. The goal-directed actions are another important issue for Rolf Godoy. The goal-points during the process of perceiving and acting, are positions or a part of the body moving in response to a stimulus, at notable moments during the musical sound. The author explains that the goal-points have features of giving us instinctual guidelines for breaking continuous streams of sound and gestures into meaningful units. The goal-point can be the combination of biomechanical, motor control, and perception of

particular streams, such as sound.

Regarding that, physical gestures can be classified as (1) interactive gestures (of two people or things) influencing or having an effect on each other, (2) impulsive gestures (discontinuous effort or the rapid accent) and, (3) sustained gestures (continuous effort). This purpose has relation with the theory of embodied cognition which explains our tendency to unconsciously imitate the gestures that we see other people making or movements that we believe other people are performing.

The chunks are based on the holistic perception of musical sound and the relation of musical, physical gestures. The chunks are classified in three different categories related to duration interval: (1) micro timescale, 0.5 seconds duration limits, (2) meso timescale, 0.5 - 5 seconds duration range, (3) macro timescale, longer than the continuation range of the meso timescale. [1] The musical phrases, as well as sequences of chunks, can present a fusion of small-scale segments whose parts are the end of gestures and the beginning of a new part, namely, co-articulation.

To establish a correspondence between physical gesture and musical structure, we proposed a method for gestural segmentation through the sub-division the musical structure into short motifs or sub-phrases. Therefore, our first action was to determine the goal-points in the score according to goal-directed sound (Figure 9) through the musical analysis. The selected fragments support the idea of chunks corresponding to the acoustic events which show clear musical direction towards the goal-point notes.

Considering that we can determine the notes onset, and consequently the time of each musical motif, we looked for the corresponding local minima in the velocity curve, in seconds. This method ensures that each unit is segmented in both streams. Hence we analyzed the sound and gestures at each particular segment. Therefore, each grouped gesture represents an approximation involving note onset motifs and the subsequent motif.

[1] Rolf Godoy explains and suggests some examples for this classification. Micro timescale results in a duration limit in which we distinguish continuity in both sound and motion, for instance, trill, tremolo, and vibrato. The meso timescale chunks are many prominent perceptual features such as timbre, dynamics, pitch envelopes, rhythm, or some perceived musical features in short segments. Finally, the macro time scale consists of sequences of meso timescale chunks.

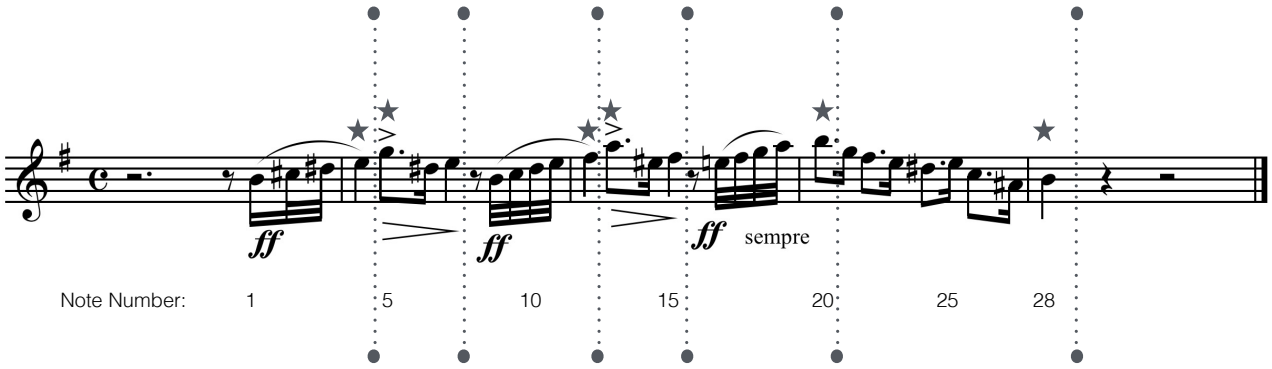

Figure 9 – Figure illustrating the musical segmentation of the Rossini's excerpt. The grey stars mark the goal-point, and the vertical dashed lines indicate the musical segments or the chunks.

4.2.3 Gestural features

The segmentation process defined the parts, hence it is possible to perform a gestural analysis. It is important to explain that we adjusted the means in each gesture to zero, equalizing the center of the trajectories at the same point.

Due to the requirements in comparing different flutists, time-warping algorithms (SENIN, 2008) were applied to the performances so that any time coordinate would correspond to the same musical event in all takes. Using the notes onsets as reference points in the timing model, we ensured a proper temporal alignment between the signals following the musical structure. This strategy was implemented to compare gestures across performances, independent of original tempo.

In a previous study, Wanderley (2002) analyzed the general movement patterns and frequencies of vertical bell clarinet movements, and the results showed gestural patterns across performances, given that musicians performed continual vertical movements while they played.

Wanderley explained that a common manifestation of continual motion occurs when a player taps their foot or moves their instruments up and down to maintain a sense of tempo. The author was also able to observe that players' motions were caused by phrase structure, showing the importance of vertical motion analysis. In this study, we also noted that this continual movement is related to the organization of musical ideas and phrases and it will be described in this study.

5 ANALYSIS

In this research, we use some complementary analysis to study ancillary movements: (1) visual analysis, from video recordings made with a (consumer) digital video camera; (2) numerical analysis, from a high-accuracy three-dimensional optical movement tracker; (3) auditive test involving all participating flutists analyzing how notes are grouped in musical phrases during different performances; and (4) self-report with flute players discussing their interpretative choices about Rossini's excerpt. We also performed a musical analysis to understand the Rossini's excerpt and the interpretative choices of flutists following this piece. Figure 10 shows the sequence which we following during the study. In this chapter, we will examine the decision of each flutist using the approach of all analysis's process.

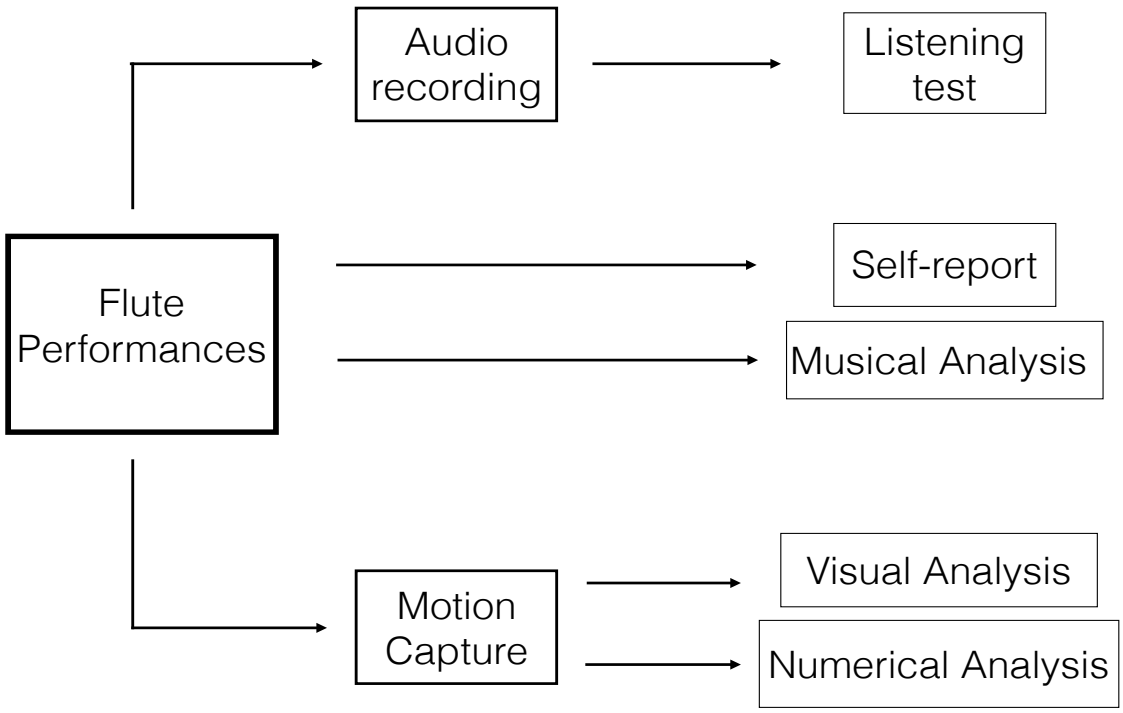

Figure 10 – Schematic diagram illustrating the flute performances analysis methodology. The analysis sequence is based on methods process from audio recordings, motion capture, and flute performances.

5.1 Musical Analysis

Gioachino Rossini was born on February 29, 1792 in Pesaro and died on November 13, 1868 in Passy. His parents were musicians, and he had a musical education while backstage in numerous opera houses where his mother performed.

According to Steen (2010), Rossini was a member of the Accademia Filarmonica of Bologna where he studied cello, piano, counterpoint and in particular the music of Haydn and Mozart. Rossini also was employed as a continuo player and *répétiteur*, and sang in an opera in Bologna when he was a child.

His best-known works are operas, such as *The Barber of Seville*, *Otello*, *La Gazza Ladra*, and *Guillaume Tell*. However, Rossini also composed vocal music, such as *Petite messe solenelle*, and chamber music.

The studied piece was composed for wind quartet, and the selected excerpt is the beginning (bars 1-4) of the second movement, *Andante*, of Wind Quartet No. 2, in G major. Although the musical analysis includes the beginning, middle, and end of a piece, beyond all voices involved, we decided to analyze just the excerpt performed by musicians in this study, given that it is the only part that the musicians played. Upcoming analysis suggests a harmonic analysis and its melodic relations, considering that the passage is composed of all three players playing the same melody. We will use the analysis description suggested by Kofi Agawu [1].

The excerpt begins with the sounding of voices of the upbeat leading into the tonic on the downbeat of bar 1 (E minor, as I). This description is the moment which we consider the first motif [2]. The second motif also shares this sense of directness in time, and it aims to achieve the tonic, E minor. The presence of D-sharp creates a sense of anticipation given that it is the seventh of E minor (Figure 11). In our analyses, we consider two main musical motifs: (1) upbeat and downbeat motif, Bars: 0 - 1^1 / 1^4 - 2^1 / 2^4 - 3^1; (2) accentuated note motif, Bars: 1^2 - 1^3 / 2^2 - 2^3, and the grouping of two motifs, which we call sub-phrases.

The second sub-phrase also presents the destination to the downbeat, dominant (B major), in which F sharp is the fifth note. Also, in the next motif, there is a conduction to B major, in which the E sharp is a seventh of F sharp, the secondary dominant (V/V). This kind of context is relevant because although flutists grouped the musical phrase in different ways, they kept respecting these melodic features.

The upbeat of the second bar also conducts to the tonic, with B as the fifth note. The repetition, in this case, seems a constructed force as progression III (G) - IV (A) - V (B) (figure 11, blue markers). However, the last upbeat of this progression incorporates the function of co-articulation. Thus, the motion of recent upbeat lets us recognize that the destination will be different. The end of progression (B - note 20) represents an attained goal and the beginning of a new musical idea. In bars 2^4 - 3^1, Rossini repeats the upbeat's idea and extends it, leading finally

[1] According to Agawu (2009), the superscripts are utilized to locate a particular beat within the bar. Consequently, 2^1 indicates beat 1 of bar 2, 2^2 is beat 2 of bar 2, and so on.

[2] Oxford Dictionary of Music (www.oxfordmusiconline.com) defines motif as "a short musical idea, melodic, harmonic, rhythmic, or any combination of these three." The size of the motif can vary, but it is commonly considered shorter than a musical phrase. The motif is usually identified by the term "figure" or "idea." The musical phrase is a term used from linguistics and means a musical unit of various lengths. It carries a melodic intention, and the term "phrasing" regularly employed by the subdivision of a melodic line.

to a cadence to the dominant (B major) in which the notes E, C, A sharp (figure 11, red marker) is the Italian sixth chord.

The melodic progression constitutes the norm of coherent and meaningful tonal order which may be noted as movement from one stable note (G) to another, more stable point (B).

Other material identified in Rossini's piece was ascendent and descendent chromatic pitches. The recurrence of these intervals (figure 11, purple markers) generates the idea of tension and arouses expectations. The repetition of these intervals seem to generate the idea of *Arsis* and *Thesis* [3]. The flutists' intentions emphasized the notes *thesis* which were performed through their sound and motion, and they are recurrent during the excerpt's performances.

Elizabeth Margulis (2014) has studied the repetition and its implications to listeners, musicians, and composers. The author explains that learning/level-shifting, segmentation, and expectation are primary roles identified in studies on musical auditory repetition for the audience. According to Margulis, the insertion of repetition can create an impression of intentionality. Therefore, the repetition draws out the signature of the individual as well as his/her connection to the surrounding.

Bars 0 - 1^1 = conduction to the tonic, E minor.

Bar 1^2 - 1^3= conduction to the tonic.

Bars 1^4 - 2^1 = conduction to the dominant, B Major.

Bar 2^2 - 2^3 = conduction to the dominant.

Bars 2^4 - 3^1 = upbeat in V (B Major) to tonic (E minor).

Bars 3^3 - 3^4 = Italian sixth chord.

Bars 3^3 - 4^1 = cadence to dominant.

[3] Arsis and thesis, in prosody, means an accented (arsis) and unaccented parts (thesis) of the metre of a poem. According to Grove Dictionary (1947) the terms Arsis and Thesis also refer to the stronger and weaker parts of a musical measure.

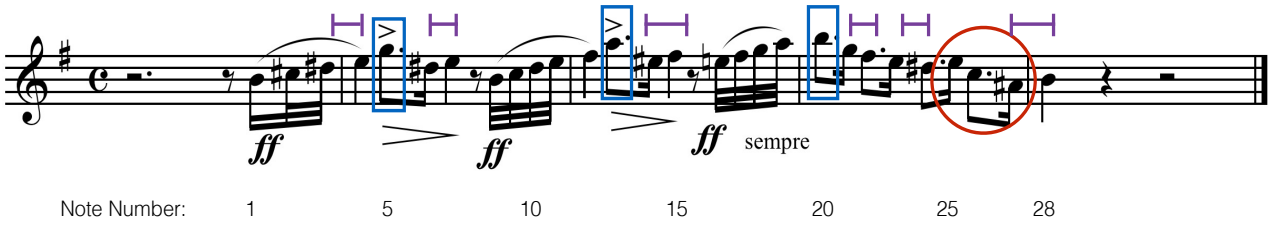

Figure 11 – Woodwind Quartet by G. Rossini, beginning of *Andante* (bars 1 - 4).

5.2 Visual Analysis

This discussion here is part of a continuing effort to quantify and analyze the gestures of musicians in order to understand their origins and communicative utility. The considered hypotheses is the relation between the manipulation of sound and grouping of notes by musicians and their ancillary gestures.

Based on the visual analysis, from video recordings, and using the method Laban-Bartenieff Movement Fundamentals, we identified relationships between body and space that produce shapes in constant movement. Laban described movement through the four inter-related categories of Space, Effort, Shape and Body. However, as previously stated, we focused on the flute's trajectory which musicians performed in the space and their possible relation with musical ideas. Although the first analysis was performed through the visual observation of video recordings, we decided to exemplify the identified shapes in three dimensions from motion

capture data.

We consider it appropriate to observe the class of shape of these movements, considering them as gestures. According to Chagnon et al. (2005), the "shape" could be extremely useful for observation of musicians as a performer's musical intent, recurrently expressed simultaneously in sound and gesturing qualities. Also, the characteristics of opening and closing actions can be more precisely described by showing the direction and plane through which the body is moving or changing.

There are three modes of shape changing: (1) flow, (2) direction, and (3) carving. The shaping qualities are primarily related to breath, given that both are separated by opening (inhaling) and closing (exhale) actions. The shaping features are extensions or reflections of the motion as in the breath. The opening-closing shaping qualities are (1) rising-sinking, vertical (2) advancing-retreating, horizontal, and (3) widening-narrowing, sagittal, through the manipulation of the body.

Opening and closing actions can be explained by showing the direction and plane through which the body is moving. The directional shape can be a cyclical or linear motion, which the body is moving in space aiming to achieve the particular point. Finally, the carving shape involves the interaction between two bodies in mutual adaptation.

During the visual observation, we analyzed all recorded excerpts, given that each one presents a particular feature and we considered it necessary to include all of them. We recognized different shapes in the flute's trajectory, such as cyclical patterns, a motion forward/backward, up/down, and half of the cyclical gesture (figure 12). We also perceived that each shape could be related to the performer's musical intentions, given that some gestures seemed similar among flutists.

The cyclical motion was identified when musicians grouped the musical phrase acoustically. For instance, figure 14 shows the relative movement of the flute played by flutist 2 during the performance of excerpt *Allegro meno mosso* of Woodwind Quartet by Heitor Villa-Lobos (figure 13). In this case, we chose to show this excerpt, due to the movement's features, the broad and unique movement can suggest the relation between physical gesture and organization of the unique musical phrases. During the visual analysis, we perceived that the observed physical gesture leads to define that this excerpt must be grouped in one single musical idea, corroborating with the physical gesture. Hence, our hypothesis was confirmed.

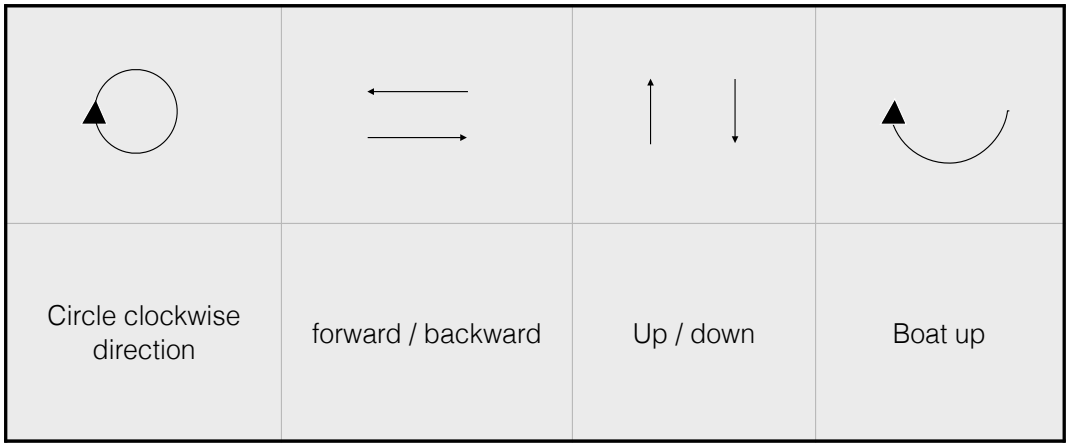

Figure 12 – Four selected shapes: full circle (circle in clockwise direction), forward and backward, up and down (vertical motion), and half circle motions (also in clockwise direction.

The shape in figure 14 was segmented using the same procedure as Rossini's piece and the all movement segments were grouped in a unique gesture.

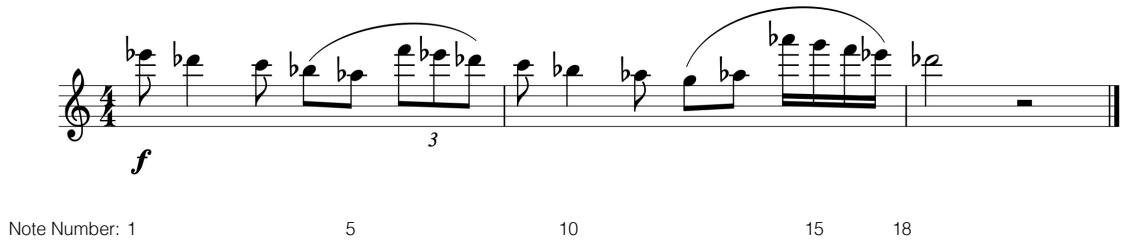

Figure 13 – *Allegro meno mosso* of Woodwind Quartet by H. Villa-Lobos.

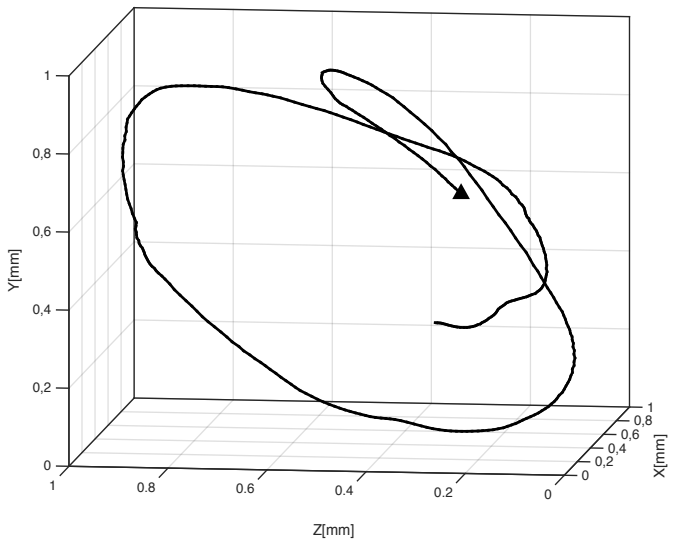

Figure 14 – Cyclical motion performed by flutist 2 during the performance of Villa-Lobos' excerpt. The triangle registers the initial point of gesture.

It is important to explain that it is only one viable idea for grouping this excerpt in phrases. There are others possibilities. Flutist 4, during his interpretation of the same excerpt, performed gestures with a rhythmic sense, given that the motion of the flute corresponds to the specific instance of the pulse. Figure 15 represents the shape, forward and backward, and the possible relationship of this gesture and the time sense of music, demonstrating another interpretive choice. We perceived that the shape, forward and backward, also presents relation with the sense of time, given that the position of the flute in the fore front corresponds with the pulse of this piece.

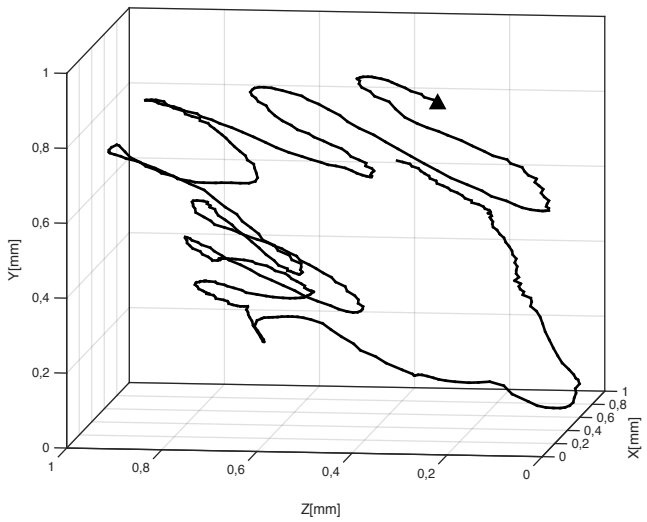

Figure 15 – Forward and backward motion performed by flutist 4 during the performance of Villa-Lobos' excerpt. The triangle registers the initial point of gesture.

The up and down movement was identified in other wind instrument research (TEIXEIRA et al., 2015; WANDERLEY et al., 2005) and results have suggested that this particular motion also is related to the rhythmic structure of phrase. The authors have pointed that the motion up/down (vertical movement) might be necessary to keep regular features associated with time. During our analysis, we identified two different gestures to represent the same sense of time, up/down and forward/backward. It can be related to the individuality of each musician and his/her way to move in the space, given that the movements tended to be idiosyncratic. Figure 16 shows the vertical movement of the flute in a performance of flutist 4 of Rossini's excerpt. One can perceive that the vertical motion of the instrument appears exactly in the same point of the beat (triangles).

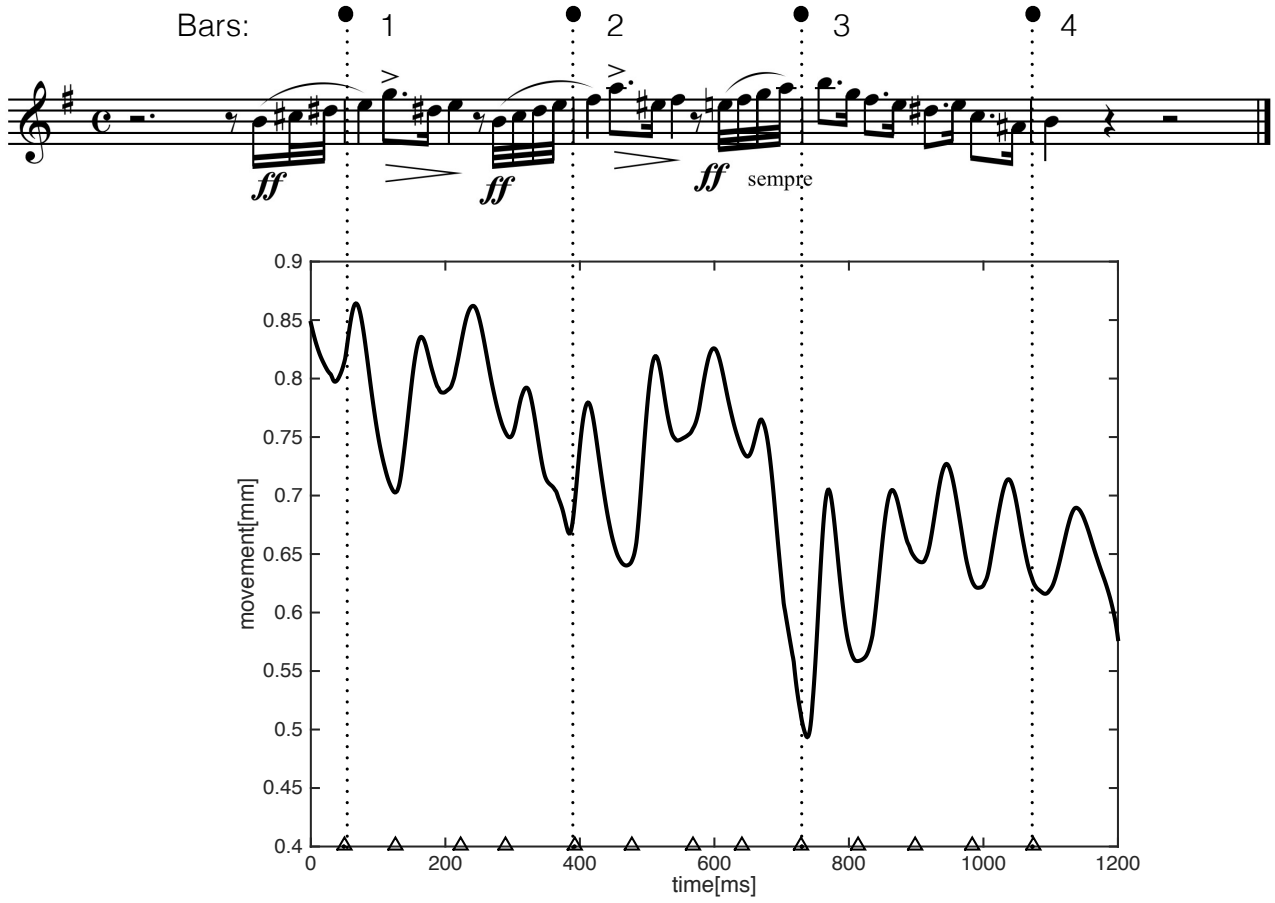

Figure 16 – Up and down motion performed by flutist 4 during the performance of Rossini's excerpt. The triangle registers the beat of tempo.

Finally, the shape, a half circle, has been recurrent in several flutists during the grouping of specific musical motif, upbeat and downbeat (figure 17). The relation between the gesture (half circle) and this particular musical part can be explained due to the mental representation of this motif. This short part consists of the *anacrusis* in which the upbeat clearly drives the point that we consider as the goal point, assuming that the downbeat is the strongest part of the motif.

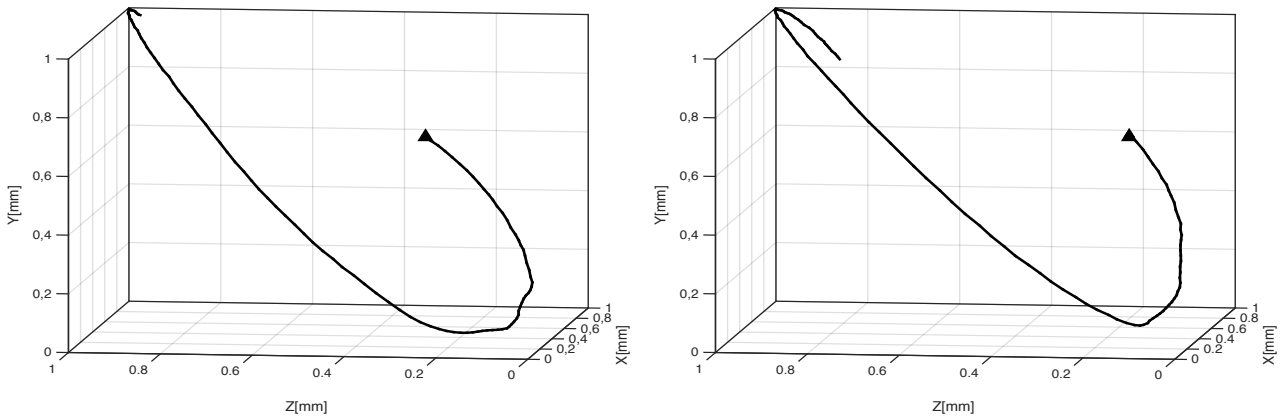

Figure 17 – Half circle motion performed by flutist 2 during the performance of musical motif 1 by Rossini. The triangle registers the initial point of each gesture.

Marc Leman (2008) reported that the narrative and experimental viewpoints may be integrated through a particular approach to the concept of embodiment. The human body is thereby understood as a mediator between the musical mind and the physical environment, and gestures can be perceived as the way in which this mediator deploys itself in space and time.

The author explains that depending on the viewpoint, the gesture can be analyzed: (1) as simple body movement (starting with kinematics and kinetics); or (2) as an expression of human intentionality which is implied by body movement.

5.3 Individual Analysis

Based on the listening test and acoustical analysis, we perceived that flutists often grouped the musical ideas (figure 18) in short motifs (red markers) or longer sub-phrase (green markers). Because of these attempts, we decided to divide the excerpt into two musical segments: (1) a short demarcated part, a musical motif; (2) a longer sub-phrase. Besides this, we separated the excerpt into two sections: A and B (grey markers). The intention was to verify future recurrence of gestures when musicians play short motifs, as well as individuality on gesture patterns related to musical phrases that may produce original interpretative intentions.

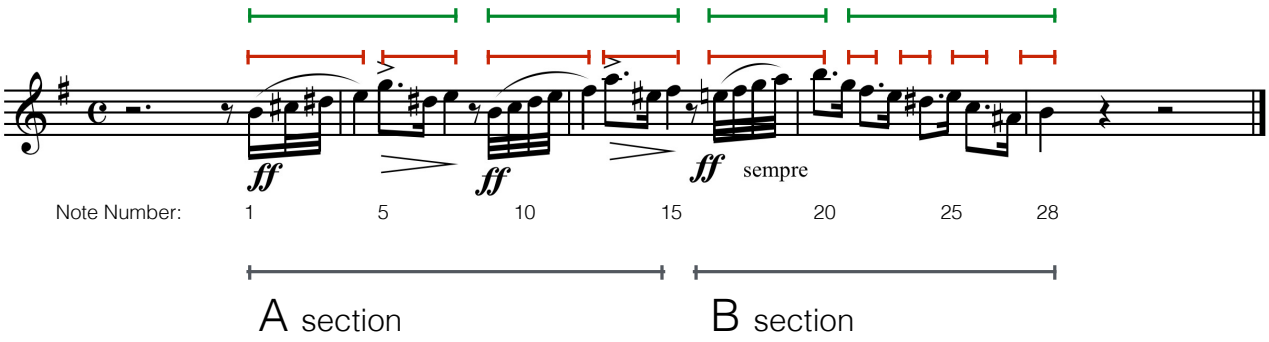

Figure 18 – Grouping musical ideas by flutists. The short demarcated part, the musical motif in red and a longer sub-phrase in green. A and B sections in grey lines.

These selected motifs were chosen due to their particular characteristic, the representation of an idea, which can be only one isolated part or the possibility to integrate distinct musical phrases. The small part consists of the upbeat and the downbeat, motif number 1, and can be considered as a unit used by Rossini to compose this excerpt. Motif 1, in which the upbeat clearly drives to the downbeat (note 4), which we believe to be the goal point, assuming that the

downbeat is the strongest part of this motif. Observing the results of the listening test we argue that flutists identified specific intentions to conduct at the last bar, considering that the notes 22, 24, 26 and 28 as *thesis*, and given their position in the bar.

Despite the fact that the flutists were asked to play in different conditions (solo, following the clarinet and following the bassoon), the gestures performed in the selected motif appear similar in all situations. On the other words, the different conditions do not affect the features of gestures within the defined musical motifs in the excerpt. We perceived a recurrent pattern in the flutists in all settings.

This result reinforces the hypothesis that there are commonalities in musicians while they play a codified musical part. It supports the relationship between physical gesture and musical gesture or motif, especially because the upbeat and downbeat (*Arsis* and *Thesis*) given that this is the most important material of this excerpt. No influence of gender was observed. That said, we will use the pronoun 'he' to designate the flutists involved, aiming to preserve their identity.

Due to the small population observed (three male and one female), we will present each flutist's analysis separately, given that the influence of different contexts may be a significant factor in determining movement style. Musicians who work in the orchestra develop different skills, while other musicians teach. Analyzing of the performances of Rossini's quartet indicated that individual flute players tended to maintain relatively consistent patterns of movement throughout different conditions and takes.

According to the visual analysis of each segment, we recognize repetitive patterns in the specified grouping of musical ideas. The individuality in each musician involved is noticeable, given that each one performs a particular shape in the trajectories. Therefore, although the gestures are different among instrumentalists, there are the idiosyncrasies of each musician.

5.3.1 Flutist 1

Flutist 1 incorporated similar gestural features during the performance of the musical motifs. It indicates a dependence on motion and the structure of the piece being performed. We can perceived similar shapes during his interpretation, however these may vary in amplitude or in direction.

When we look at the differences in gestures, we observed strong relations between the shapes of flute's trajectory and the musical motif. In motif 1, is interesting to notice the similarity among the gestures depicted in figure 20, at the first time (motif 1.1) and the last time (motif 1.3). Besides the relationship of these shapes and the organization of musical phrases performed by flutist 1, these arguments suggest that flutist 1 grouped the notes into short musical phrases, separating motifs one and two. Flutist 1 also grouped the last phrase into small segments (figure 20). Considering the fragmentation between motif 1 and 2, and segments in the last bar (*Arsis* and *Thesis*), we identified a cyclical motion as a grouping of an idea.

However, some gestures of the motif 1 and segments present a shape as a circle while other seem to be an open gesture. The cyclical motion corresponds to motif 1.1, 1.2, and segments 1.1, 1.2 and 1.3. The exceptions are the last one (motif 1.3) and the last segment (1.4) which tend to be a gesture without an intention to return. A hypothesis that could account for these findings is that the moments mentioned (motif 1.3 and segment 1.4) are at the end of musical phrases or of the beginning of a new musical idea. In a previous explanation, considering that each phrase presents different features, the excerpt can be divided into two sections: (1) Bars 0 - 3^1 (2) Bars 3^1 - 4^1. The gestures performed by flute player 1 in these precise moments are different from others, changing in direction.

Within the shape which represents motif 1, number 1 and 2 were performed closing the shape while number 3 presented a continuous shape, changing the direction and conducting another musical phrase. The same occurs during the performance of the last bar, the segments 1, 2 and 3 showed a cyclical motion while the last one presented an open gesture. The first motif in number 3 and the segment number 4 are apparently present a similar movement probably because they can be considered as co-articulation (figure 19, red gesture). The gesture presents a different direction without closure like a circle.

Figure 20 shows the gestures in all musical motifs and each segment of the last musical phrase (Segments 1, 2, 3 and 4) performed by flutist 1. We chose to show just the last take in one experimental condition trying to identify the shape of each gesture with more clarity. Figure 23 shows gestures during the three experimental conditions.

Considering the fragmentation between motif 1 and 2, and intervals in the last bar (*Arsis* and *Thesis*), we identified a cyclical motion as a grouping of an idea. Additionally, the gesture of the motif 1 number 3 and the segment 4 moved to another plane. The same occurs in the score, given that these musical moments can be viewed as co-articulation or end of an idea. Figure 19 shows both gestures with and without a tendency to return an initial point of motion.

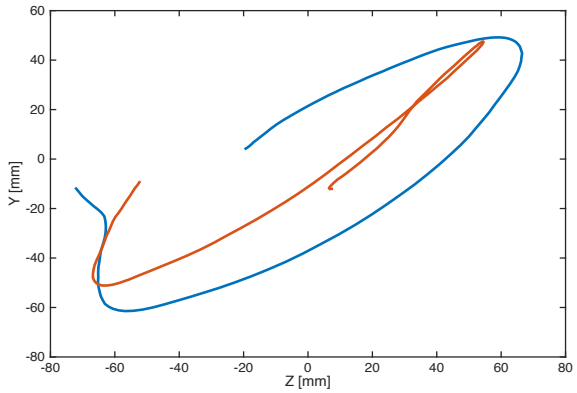

Figure 19 – Gestures with tendency to return (blue shape) and gestures without tendency to return (orange shape).

The gestures that correspond of the second motif present a fast upward movement of the flute, due to the accentuated note. This idea is consistent with previous work (WANDERLEY, 2002) describing this action like a fast sweeping movement of the clarinet bell in particular moments (*crescendo mf* to *ff*) of the Domaines by Pierre Boulez. This musical structure requires of musician sound's projection which can also be displayed in the motion such as an interactive gesture influencing or having an effect on the sound. The author explained that looked for the same gesture in another musical piece, First Clarinet Sonata by Johannes Brahms, but it not is found. This observation indicates a dependence on the structure of the piece being performed.

During the listening test, flutists considered that performer 1 organized their musical phrase in short motifs as shown in figure 18 in red lines. During his self-report, the flutist explained that his intention was performed a strong accent in the notes 5 and 13 and to provide a fragmentation between two musical ideas. He also mentioned increased energy in the accentuated notes aiming to exaggerate the articulation between notes 4-5 and 12-13. He pointed to the intention to emphasize certain points in his interpretation which were reflected in the movement.

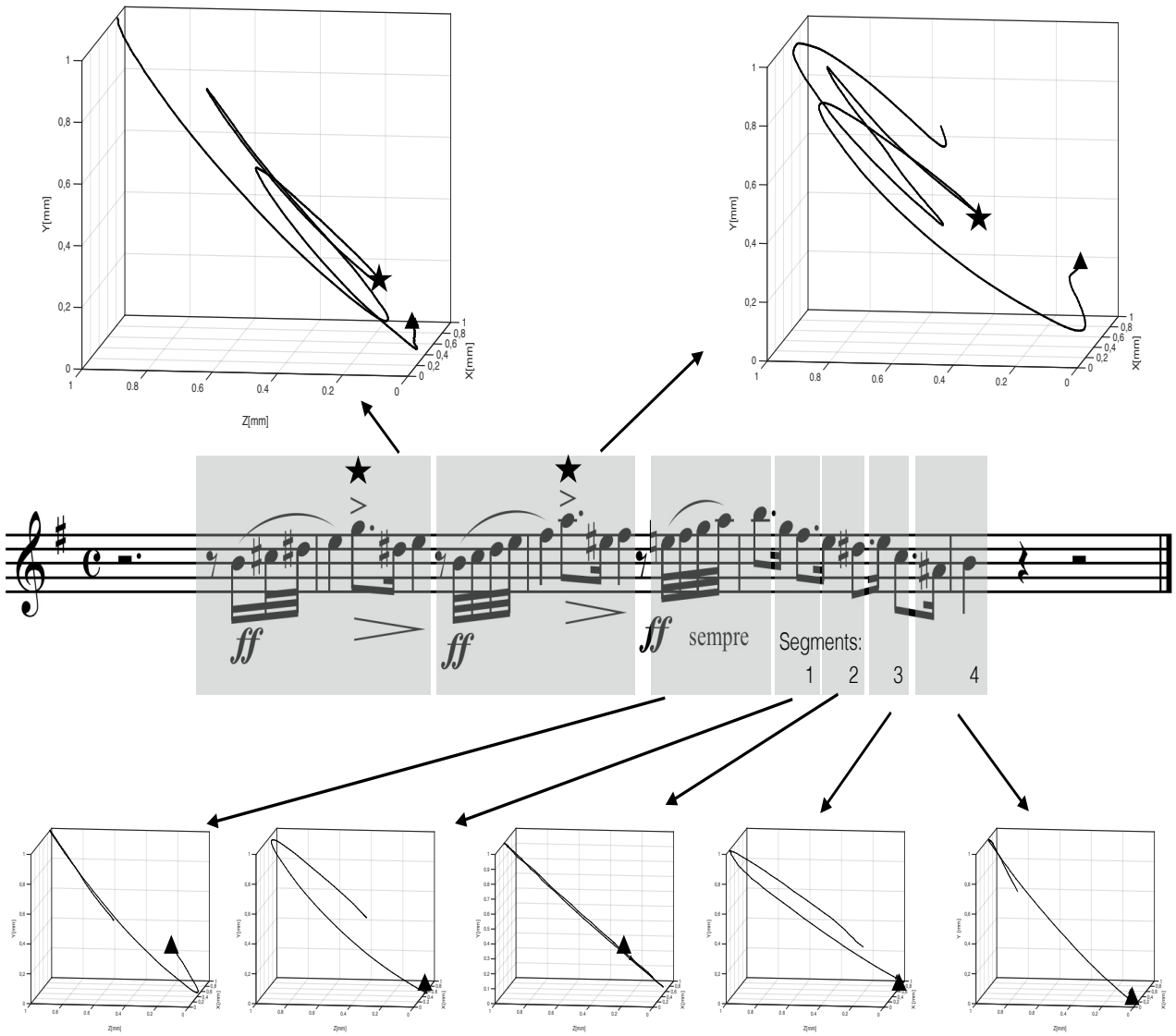

Figure 20 – The 3D trajectory of the flute performed by flutist 1 in his fourth interpretation during the solo condition. Gesture grouped in sub-phrases considering the two musical motifs. The black triangles mark the initial point of the gesture (musical motif 1), and the black stars marked the second part of the gesture (musical motif 2).

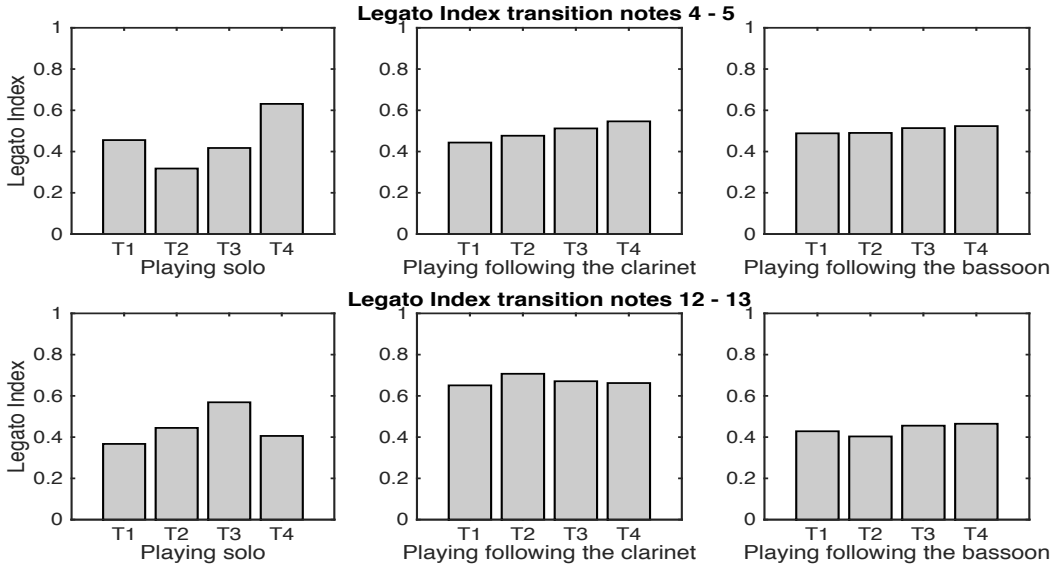

Figure 21 – *Legato Index*, the transition between the notes performed by flutist 1. Rows: From top to bottom: notes 4-5 and notes 12-13 in all takes (T1 T2 T3 and T4). Columns: Left to right: Playing solo, playing following the clarinet, and playing following the bassoon.

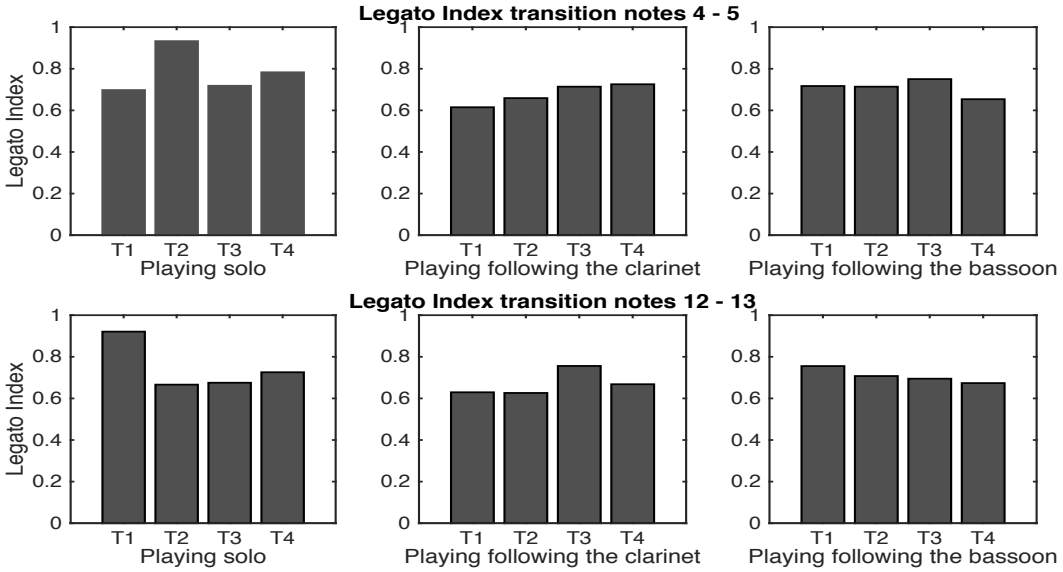

Figure 22 – *Legato Index*, the transition between the notes performed by flutist 2. Rows: From top to bottom: notes 4-5 and notes 12-13 in all takes (T1 T2 T3 and T4). Columns: Left to right: Playing solo, playing following the clarinet, and playing following the bassoon.

Analyzing the *legato index*, we can observe the transition between notes 4-5 and notes 12-13 considering the energy's decay among them. As previously stated the *legato index* points to ideal legato with the value equal to 1. Figure 21 shows the *legato index* of flute player 1 of note transitions 4-5 and 12-13 in all experimental conditions and all recorded takes. However, the *Legato index*'s analysis involve the comparison of different conditions such as experimental situation, notes or instrumentalists. For this reason, figure 22 shows *Legato index*'s of flutist 2 in all takes and conditions. In this way, one can perceive the difference between the *legato index* during the intervals of notes 4 - 5 and 12 - 13.

It is interesting to note that the clarity in articulation does not indicate the separation of musical phrases. Often, musicians play separated note inside the same phrase. However, the energy's decay between notes can identify his artistic intention of ideas segmentation.

Another point is the variance of *Legato index*, during three experimental conditions. Comparing the experimental conditions, flute player 1 varied more playing solo than playing in duet. It can be due to the necessity to adjust interpretation with others during the solo performance the flutist could experiment and consequently, change his mind.

It is interesting to consider the gestural recurrence and idiosyncrasy of flute player 1, given that he performed repetitive patterns in specific parts of the musical piece independent of experimental conditions. These findings indicate that the occurrence of ancillary gestures are not randomized, given that they appear during all performances of this musician.

Figure 23 shows all gestures performed by flute player 1 during the motif 1, in all experimental conditions (playing solo, playing following the clarinet and playing following the bassoon). The aims of this figure is to confirm the tendency of regular patterns. In each segment, there are four gestures representing each repetition of the excerpt in each condition.

Flutist 1 demonstrated high consistency performing similar gestures in specific parts of the piece, beyond of correspondence with the organization of musical phrase across performances. Although the amplitude of movement did vary, the patterns maintained recurrent.

This analysis indicates that the ancillary gestures performed by musician 1 are connected to his personal interpretation of Rossini's excerpt.

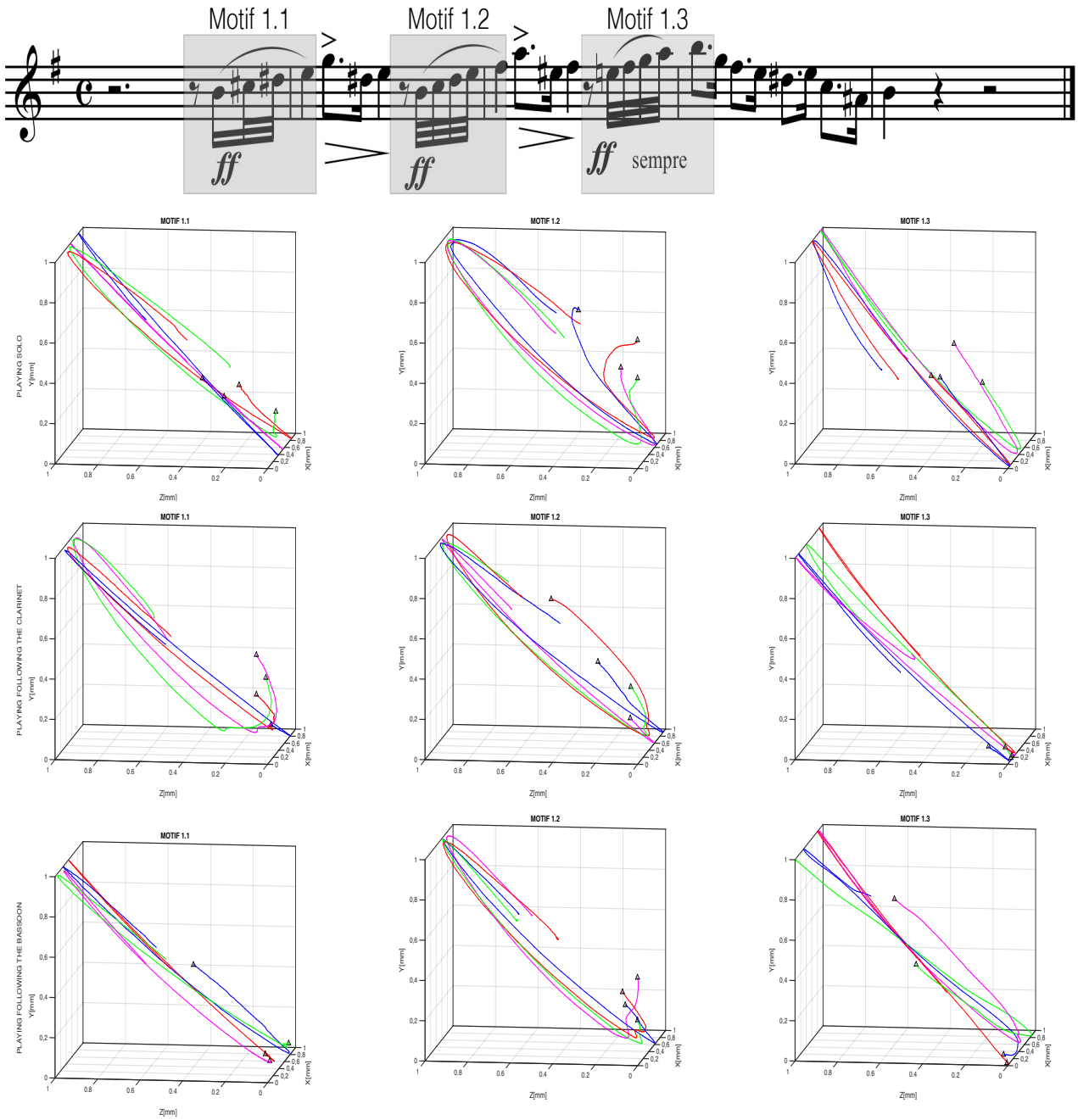

Figure 23 – The 3D trajectory of the flute in the musical motif 1 performed by flutist 1 during all experimental conditions. Rows: From top to bottom: playing solo, playing following the clarinet and playing following the bassoon. Columns: Left to right: musical Motif 1.1, musical motif 1.2, and musical motif 1.3. The four takes performed by the musician: (1) blue, (2) red, (3) pink, and (4) green. The black triangles mark the beginning of gesture.

5.3.2 Flutist 2

Flute player 2 consistently performed patterns of movement across performances in all experimental conditions. During the listening test, flutist 2 mentioned that he recognizes his performances, due to the grouping of the musical idea, in longer sub-phrases (figure 18, green markers). Other flutists, involved in the listening test, had the same impression about the expressive intention of musician 2.

In opposition of flute player 1, who performed the shape with an inclination to return to motif 1, flutist 2 played this pattern in the second motif, hence the ending of sub-phrase. These arguments suggest that the flutist 2 grouped the notes into longer musical sub-phrases, arranging motifs one and two. Consequently, the physical gestures seem different due to the direction of gesture's end.

Observing the gestural features, the second part of the shape (figure 24, black stars) presents shorter amplitude than the first section which corresponds of the grouping of musical motif 1. Considering the time of the excerpt (s) and amplitude of each gesture (mm), musician 2 tended to perform the second part of the gesture as a conclusion for the first one.

We measured the travel distance of the flute's footjoint in each motif and perceived the difference between them.

Observing these aspects, flutist 1 played two gestures coherent with musical motifs 1 and 2 while flutist 2 performed one broad gesture during the first part following a small motion. The shape, in second part, seems to be a termination of the first one, regarding the tendency to return. Figure 24 shows grouped gestures which correspond to the musical motif 1 and 2.

The flutist also mentioned the duration of the last note of the sub-phrase, regarding the importance of the end of the musical phrase. Sustaining some notes, flute player 2 felt that the "the timing carries on the music's expressiveness or swing." The flutist revealed that he tended to produce a decrescendo at the ending of the last note of each phrase, "decrescendo at the end of the phrase doesn't need to be written on the score because I always do it."

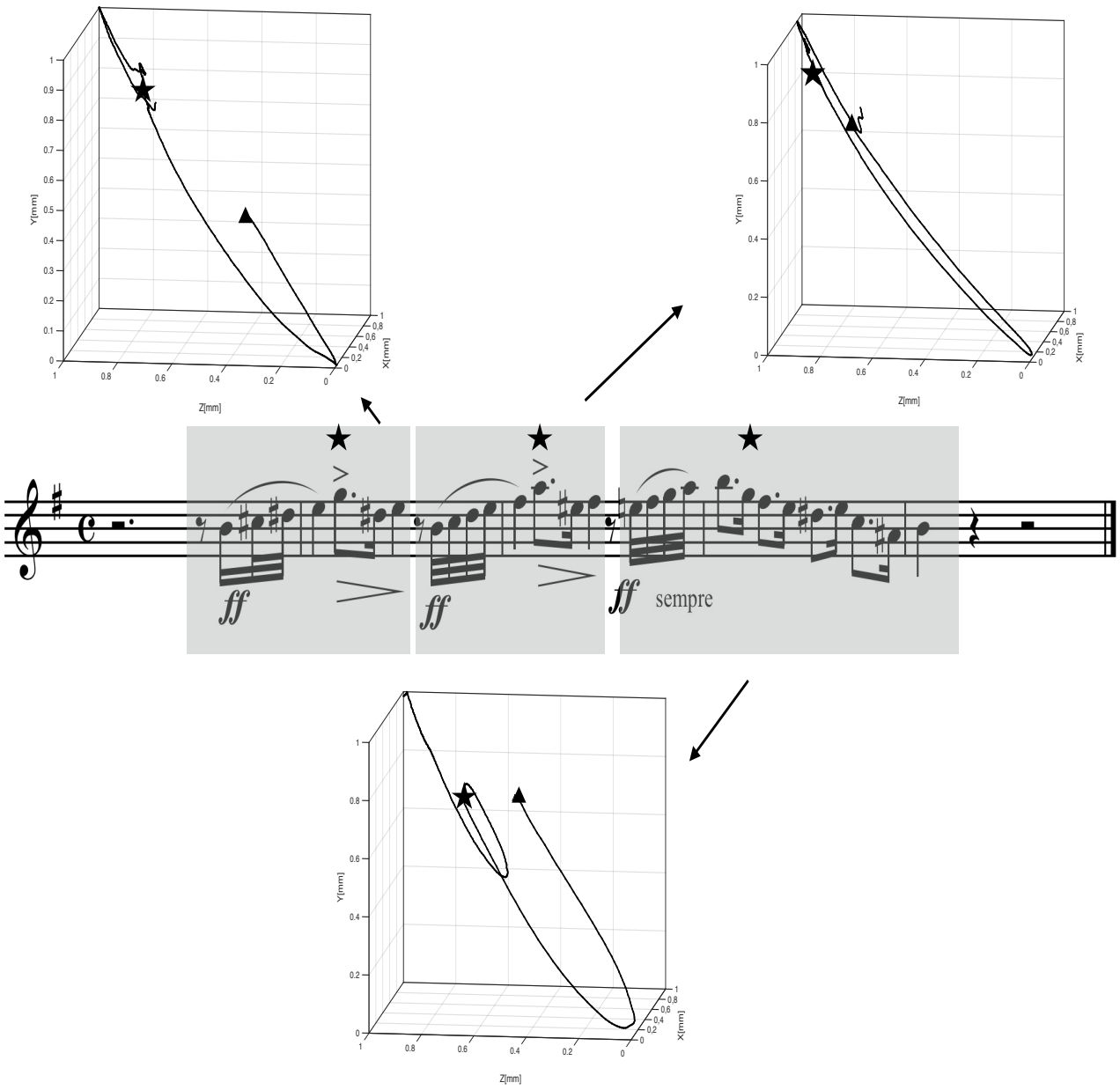

Figure 24 – The 3D trajectory of the flute performed by flutist 2 in his fourth interpretation during the solo condition. Gesture grouped in sub-phrases considering the two musical motifs. The black triangles mark the initial point of the gesture (musical motif 1), and the black stars marked the second part of the gesture (musical motif 2).

The observation of the acoustical descriptor, the sustain index of sound, in notes 7 and 15, shows that flutist 2 sustained the defined notes more than others in all conditions (solo, following the clarinet and the bassoon). Figure 25 indicates the mean of notes' duration in four takes in each state. The comparison among performers suggests that the flutist expanded the notes marking the boundary of the phrases. We consider that sustaining the notes by flutist 2 reflects the meaning that the player intended. Therefore, this strategy seems to correspond to interpretative choices during the performance, given that the results support it.

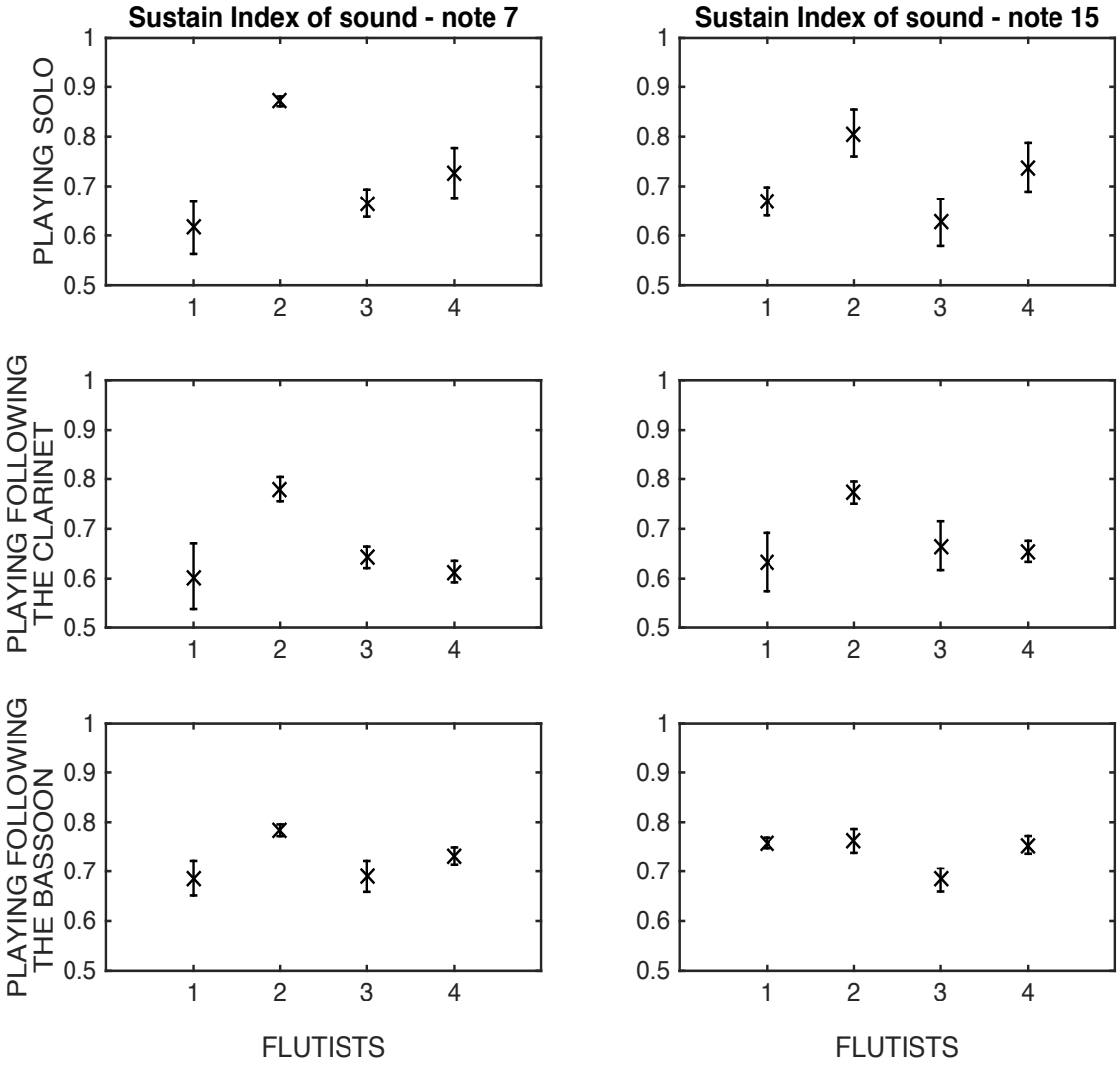

Figure 25 – Means and standard deviation of the four takes in each condition for each flutist (horizontal axis). Rows: From top to bottom: playing solo, playing following the clarinet and playing following the bassoon. Columns: Left to right: sustain index of sound - note 7 and sustain index of sound - note 15.

According to Wanderley et al. (2005), individual performers tend to maintain fairly consistent patterns of movement throughout different performances of the same piece. Analyzing the general motion pattern and frequency of vertical bell movements, they were particularly constant across performances, although the amplitude of movement did vary. Our analysis confirms these previous results, given that during the analysis of the vertical motion of flute, musician 2 maintained consistent patterns of movement during his performance, indicating the flutist's personal interpretation of the excerpt.

Figure 26 presents the up and down movement of the flute in all three experimental conditions and during all takes. Aiming to compare the performances, the *time-warping* algorithms were applied. We perceive three significant segmentations during the motion analysis at (1) Bar 1^1 (2) Bar 2^1 (3) Bar 3^1. Clearly, there is vertical motion during the performances; however, these movements which seem to be related to the sense of pulse were attenuated by the sense of phrasing. One can see significant motions between bars. These actions confirm the interpretative idea of flute player 2, to segment the excerpt into three sub-long phrases.

The gestures performed by musician 2 can be part of two levels: structural, expressing the rhythm sense; and interpretative, choosing to express the grouping of musical phrases.

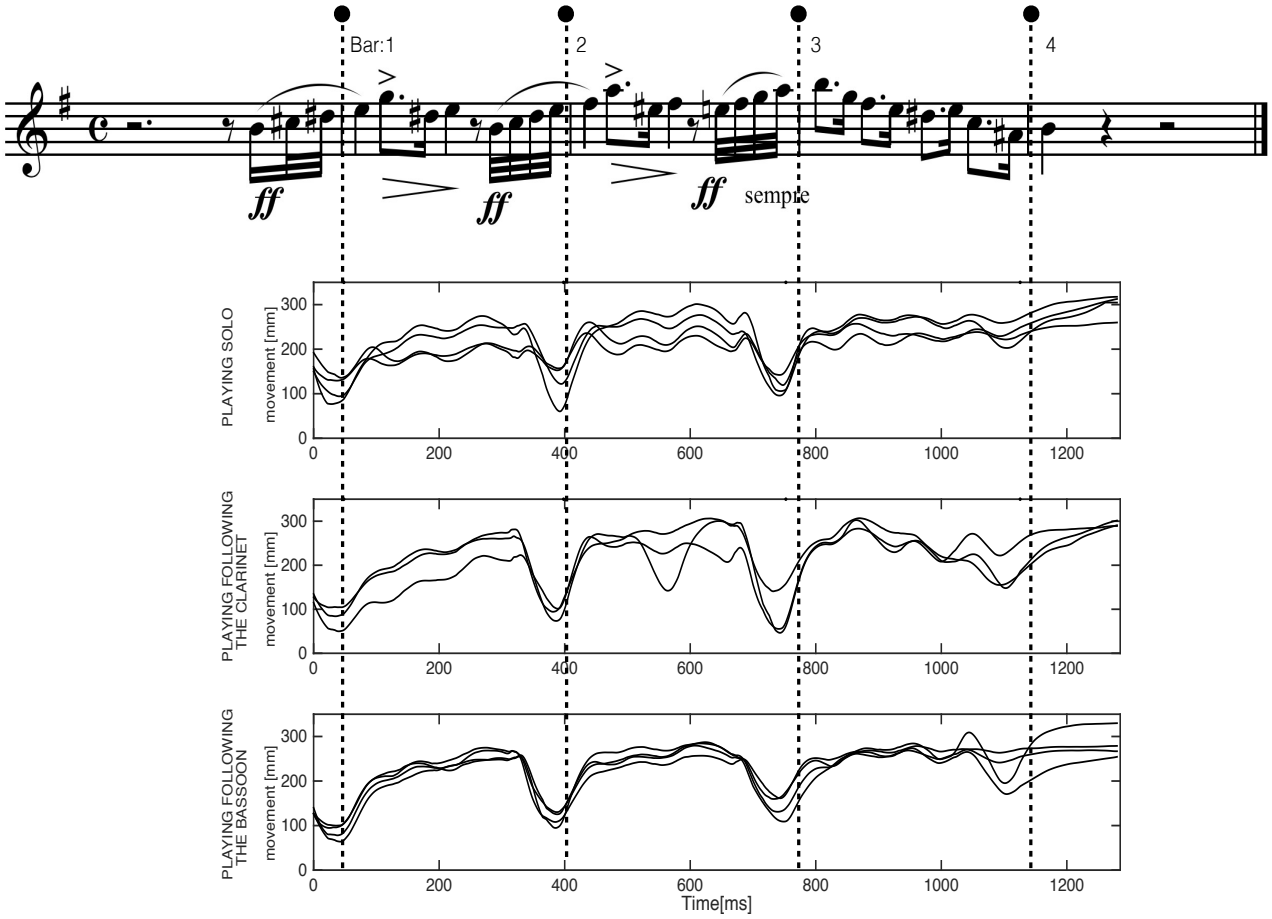

Figure 26 – Comparing time-warped graphs of vertical movement for flutist 2's flute during all experimental conditions. Rows: From top to bottom: playing solo, playing following the clarinet and playing following the bassoon.

The gestural patterns of performer 2 are consistent, although the amplitude varies. Flutist 2 displayed the least amount of motion during executions 1 and 2 in the first condition, playing solo (figure 27). He argued that these takes were used for his understanding of the excerpt. It can be noticed as a possible impact of "take effect" assuming that the performer changed the amplitude of his gestures across performances. It is interesting to consider that these differences and similarities in the gestures are performed in the specific parts which were segmented using the local minima of tangential velocity and grouped according to the musical motifs. Therefore, one may observe the strong relation between physical gestures and the organization of musical phrases. This observation points to his intention to conduct the musical phrase and demonstrates that musicians consciously make interpretative choices, organizing their musical phrases and manipulating acoustical parameters to express them.

Although musician 2 grouped both motif 1 and 2, we decided to show only the first part of the first gesture, during solo performances, considering the movement amplitude's observation (figure 27).

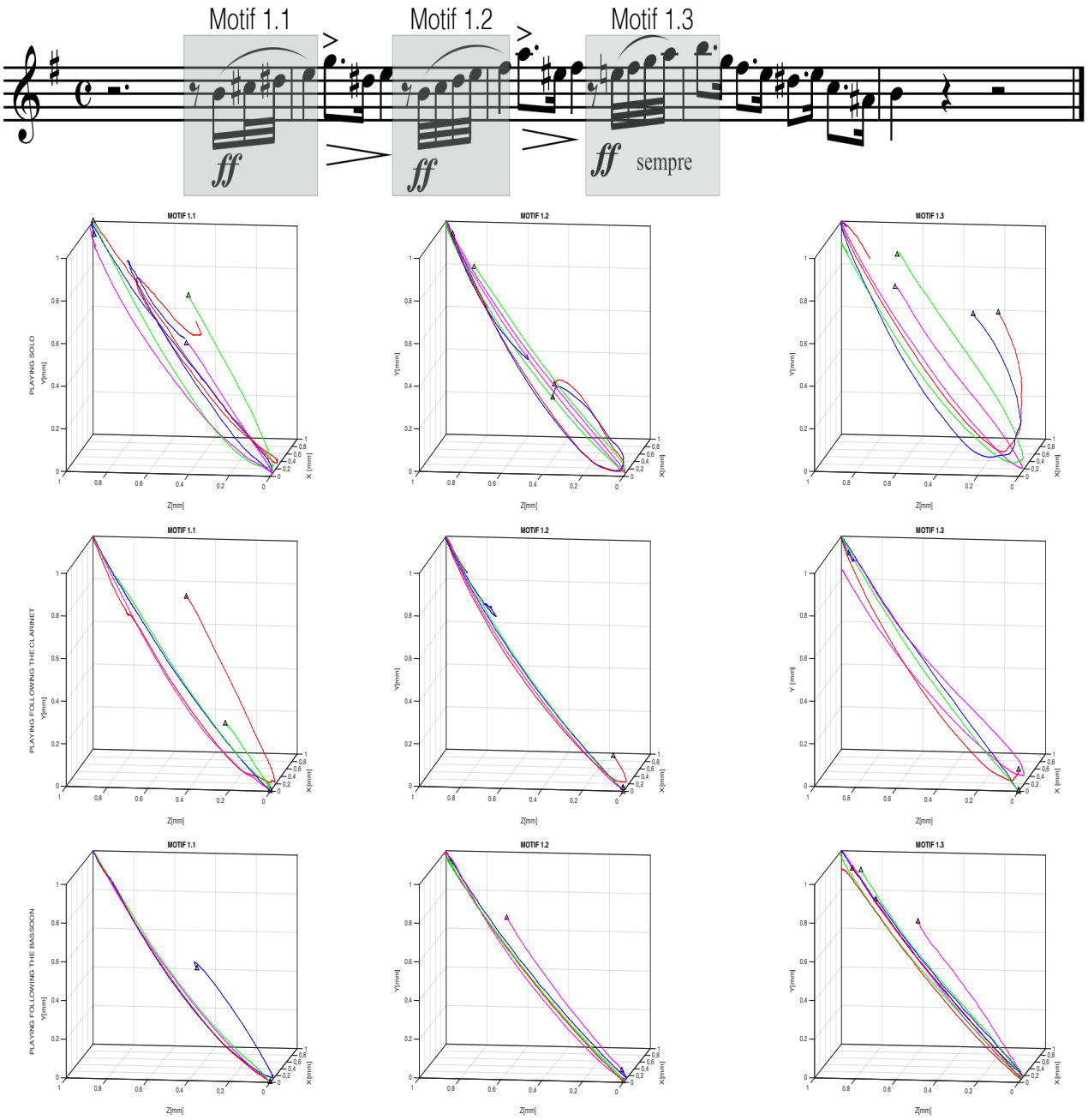

Figure 27 – The 3D trajectory of the flute in the musical motif 1 performed by flutist 2 during all experimental conditions. Rows: From top to bottom: playing solo, playing following the clarinet and playing following the bassoon. Columns: Left to right: musical Motif 1.1, musical motif 1.2, and musical motif 1.3. The four takes performed by the musician: (1) blue, (2) red, (3) pink, and (4) green. The black triangles mark the beginning of gesture.

5.3.3 Flutist 3

The gestural features of the flute's trajectory during flutist 3's performances presented a particular motion. Analyzing the vertical movement of the instrument, the motif, dotted eighth-note and sixteenth-note are represented by the instrument's vertical movement, given that the flutist moves in each part of the rhythm, sixteenth-note (figure 28, grey circles). These findings corroborate with other studies about vertical motion (up/down) and the possible relationship between rhythmic patterns and the sense of maintaining the time. Wanderley and colleagues have argued that "eliminating body movement takes away a means of being aware of the passage of time" (Wanderley et al, 2005, p.102).

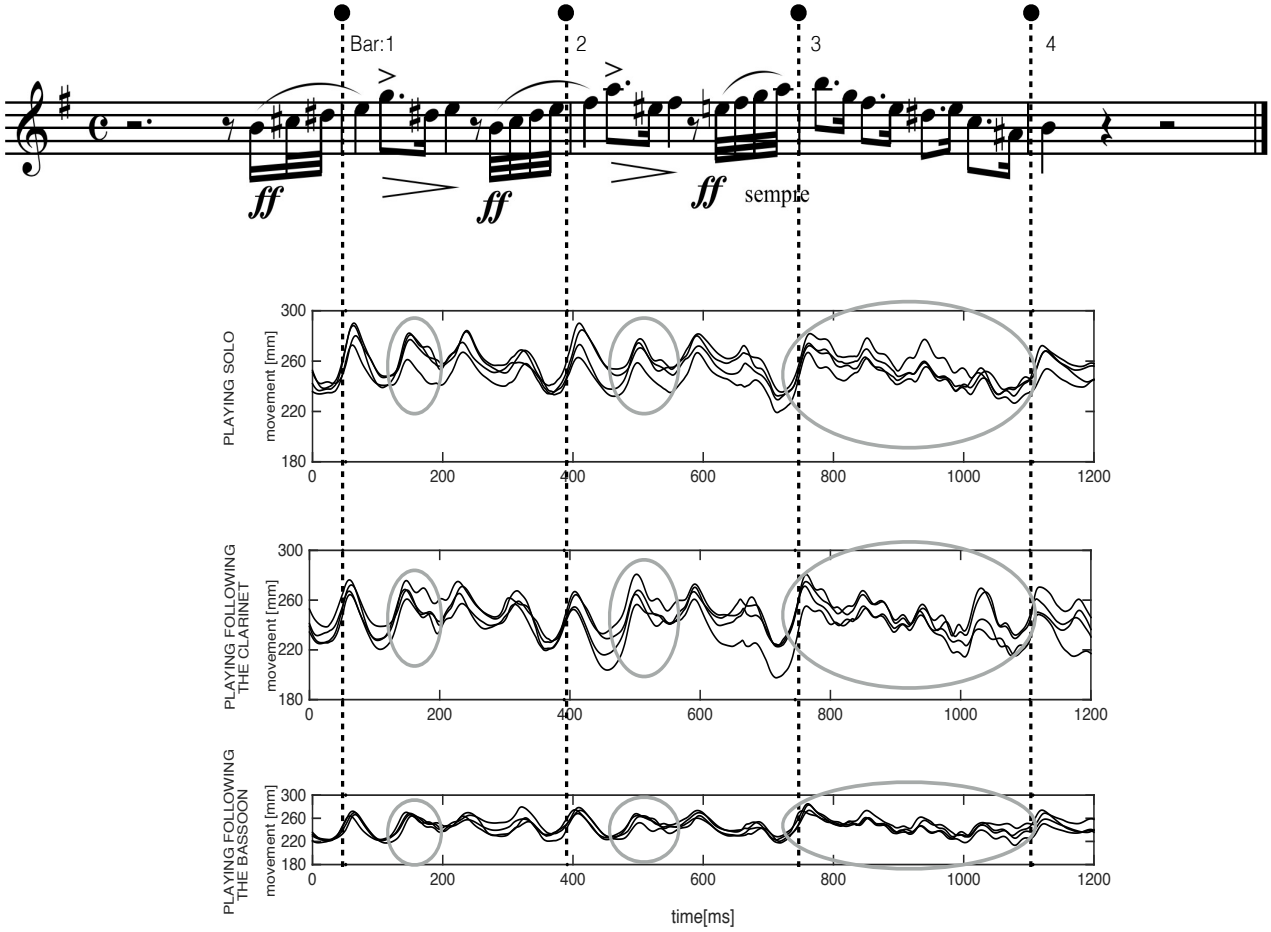

Figure 28 – Comparing time-warped graphs of vertical movement for flutist 3's flute during all experimental conditions. Rows: From top to bottom: playing solo, playing following the clarinet and playing following the bassoon. Grey circles point to parts rhythm involving motion in each sixteenth-note.

During the listening test a general judgment occurred regarding the grouping by flute player 3 (figure 18, green markers). The gestures which correspond to the musical phrases seem to be a unique shape, given that the first part (motif 1) consists of an up/down motion and the second presents a tendency to return to the same position as at the start. According to McNeill (2005), some gestures occur around an equilibrium position showing an elliptical trajectory along one plane.

There is a similarity between the first two phrases exhibiting the tendency to return to the initial motion, whereas the last musical idea follows a different direction (figure 29). This observation suggests that the flutist grouped the notes into musical phrases, considering the group of both musical motifs as a determined idea, given that they perform similar shapes. However, the third phrase doesn't present a tendency to return to the initial point, contrary, it seems to move in another direction. It could indicate that motif 1 number 3 worked as the beginning of a different musical phrase. Figure 30 shows the shape difference between the motion of motif 1 in the three times that it appears. The first and second show similarities between them, while the third time is different.

This result corroborates with the idea of phrasing, given that the first and second sub-phrases are similar while the last sub-phrase takes another conduction. The flutist mentioned that it is his musical idea organization, segmenting the excerpt into three sub-phrases. He believes that the movement changes because of his musical idea, given that the motion is recurrent during all takes in all experimental conditions.

Flutist 3 agreed that physical motion is related to music, independently of its amplitude, given that some musicians performed more motion than others. He mentioned that his intention was produce almost nothing (minimum of the) movement because he believes that his communication is focused on one aspect: his sound. For this reason, he expressed surprise in identifying his physical gestures and the correspondence with his musical gestures. He mentioned that he did not have any idea that his movement and his musical ideas were correlated.

The gestures are an integral part of the performance process, and they are possibly related to the individuality of each musician and his/her way to move in the space, given that the movements tend to be idiosyncratic. However, musicians are not aware about the relationship between physical gestures and musical phrases organization.

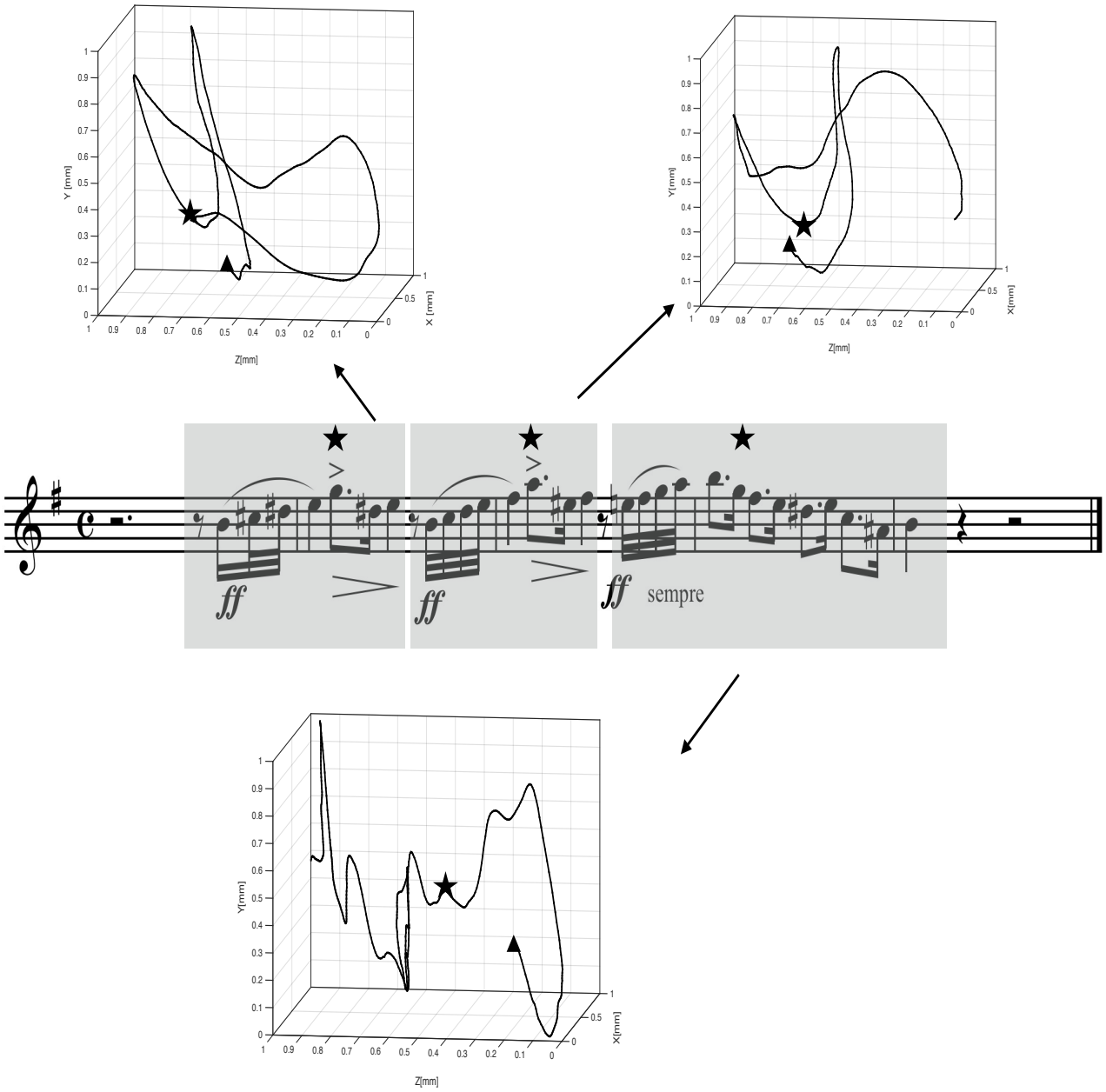

Figure 29 – The 3D trajectory of the flute performed by flutist 3 in his fourth interpretation during the solo condition. Gesture grouped in sub-phrases considering the two musical motifs. The black triangles mark the initial point of the gesture (musical motif 1), and the black stars marked the second part of the gesture (musical motif 2).

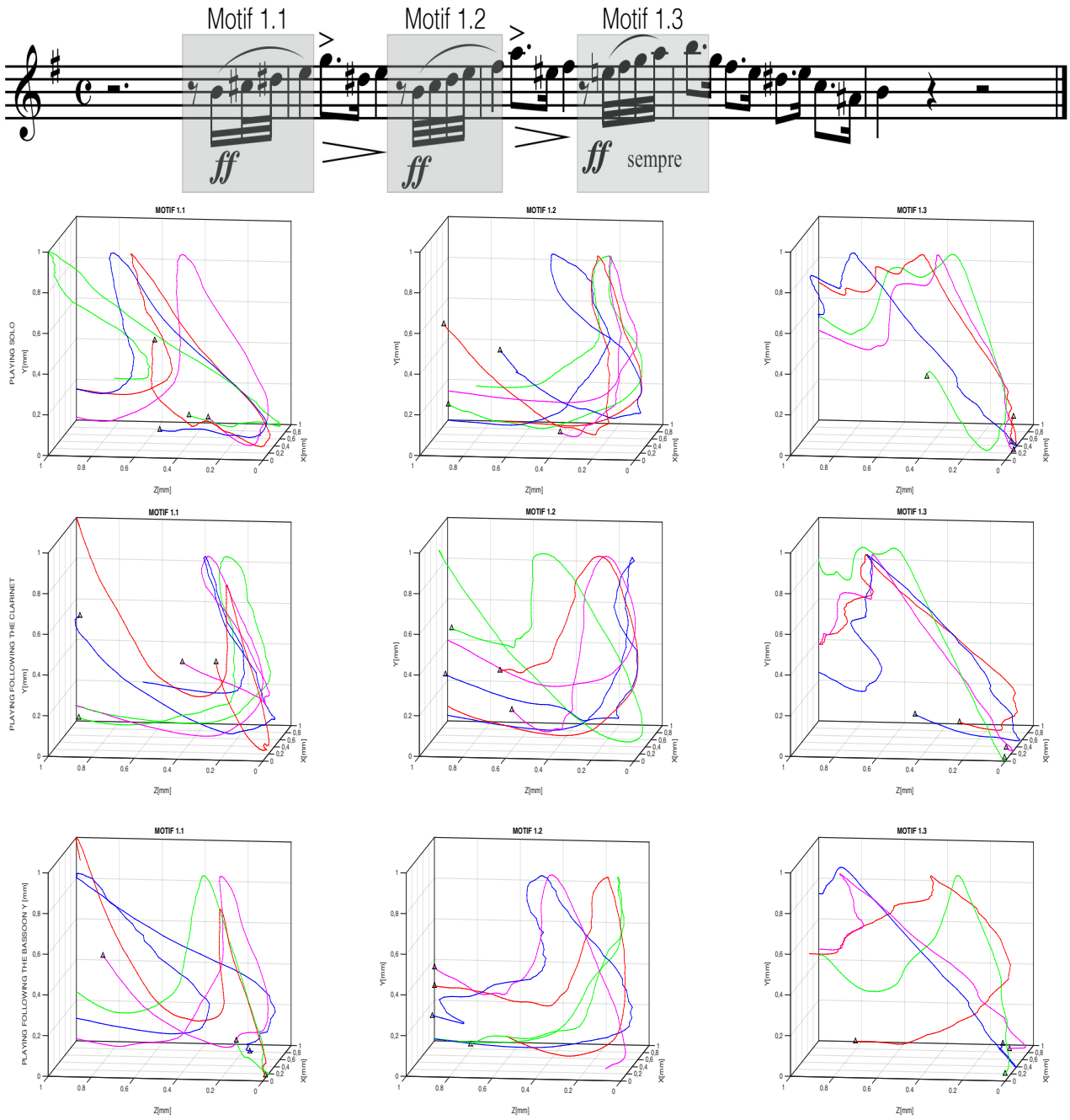

Figure 30 – The 3D trajectory of the flute in the musical motif 1 performed by flutist 3 during all experimental conditions. Rows: From top to bottom: playing solo, playing following the clarinet and playing following the bassoon. Columns: Left to right: musical Motif 1.1, musical motif 1.2, and musical motif 1.3. The four takes performed by the musician: (1) blue, (2) red, (3) pink, and (4) green. The black triangles mark the beginning of gesture.

5.3.4 Flutist 4

The relationship between motion and sense of time is recurrent during flutist 4's performances. As previously identified (section 5.2) his particular movements, forward-backward motion, and up-down movement are continuously detected in his performance. These gestures seem to be related to the beat (figure 31). It can be linked to the individuality of flute player 4 and his way of moving in the space.

Figure 32 shows gestures grouped in musical motifs. In this case, the motion is similar for all involved segments during a performance, suggesting more focus on the sense of time. One can see that all gesture sections present the tendency of forward and backward motion.

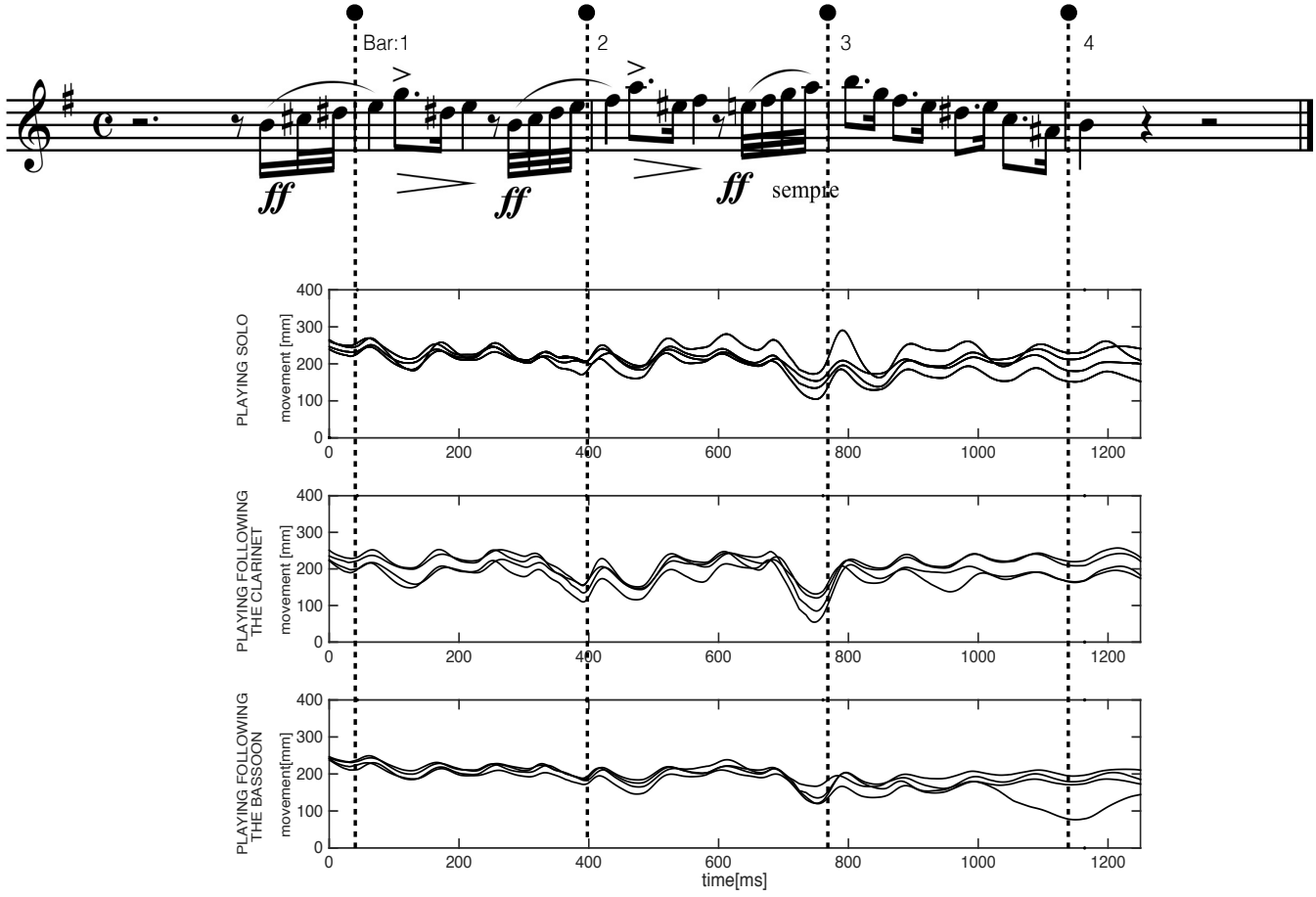

Figure 31 – Comparing time-warped graphs of vertical movement for flutist 4's flute during all experimental conditions. Rows: From top to bottom: playing solo, playing following the clarinet and playing following the bassoon.

In analyzing the vertical movement, it is interesting to note that there are points during flutist 4's performance which increased the amplitude of motion. The points are correlated to the musical parts in which are present possible musical fragmentations in Rossini's excerpt (figure 31).

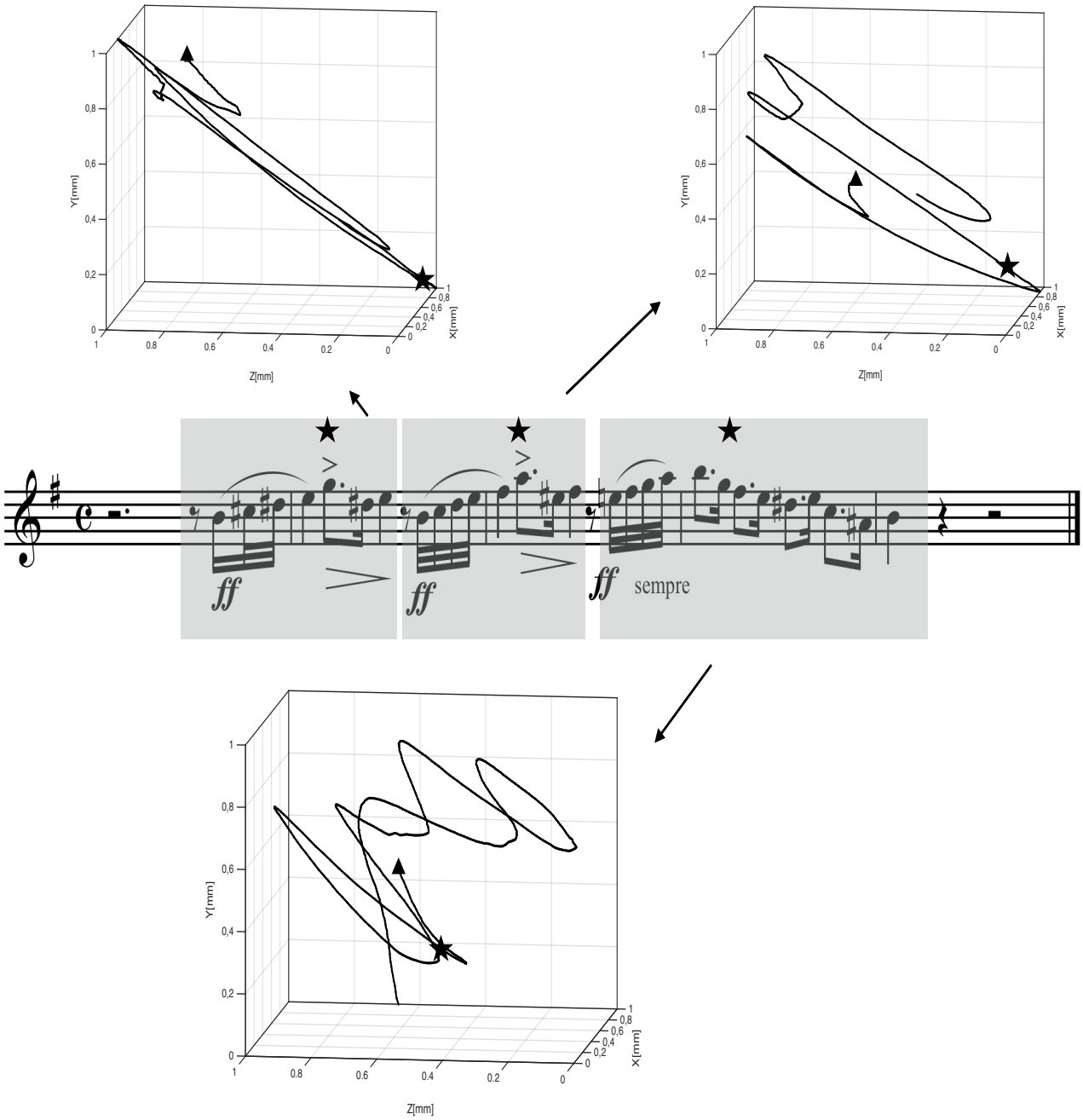

Figure 32 – The 3D trajectory of the flute performed by flutist 4 in his fourth interpretation during the solo condition. Gesture grouped in sub-phrases considering the two musical motifs. The black triangles mark the initial point of the gesture (musical motif 1), and the black stars marked the second part of the gesture (musical motif 2).

During his self-report, the musician recognized his recordings as well as his musical phrasing and timbre. He mentioned that his artistic intention was grouping notes in three sub-phrases. The increase of motion occurs exactly at the following musical progressions: Bars 1^2 , 2^2 and 3^1.

When flute player 4 played following the clarinet, the movement at the beginning of the last phrase was greater than the others. It can be related to the *rallentando* performed by the clarinetist and the fact that the flutist followed this new musical idea. The clarinet player's interpretation and the comparison between flutists and musical choices of other musicians will be discussed in the next chapter.

All of the ideas examined in this section corroborate the hypothesis of a communicative significance in the musicians' ancillary movements as part of the process of expressing the musical ideas. There was a strong relationship between their communicative intentions and to musical goal-points in the performance of the excerpt.

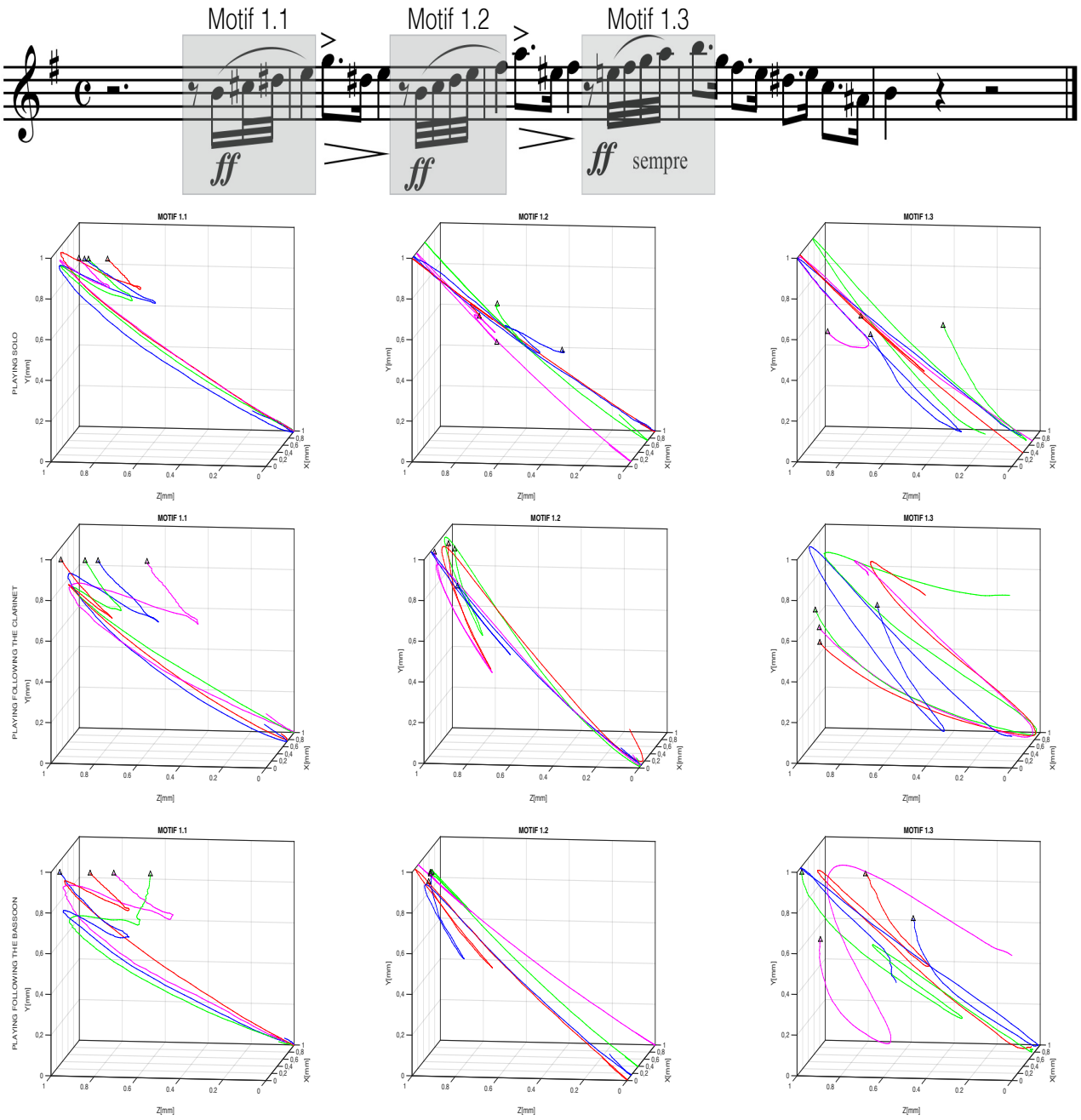

Figure 33 – The 3D trajectory of the flute in the musical motif 1 performed by flutist 4 during all experimental conditions. Rows: From top to bottom: playing solo, playing following the clarinet and playing following the bassoon. Columns: Left to right: musical Motif 1.1, musical motif 1.2, and musical motif 1.3. The four takes performed by the musician: (1) blue, (2) red, (3) pink, and (4) green. The black triangles mark the beginning of gesture.

6 DISCUSSION

As previously mentioned, the process of performance planning and practicing involves the manipulation of sound in which the musicians can emphasize or minimize various aspects of a piece. This process also includes the players making choices to group notes in phrases, emphasize harmonic features and/or highlight rhythmic units. Consequently, both principles exert mutual influence in the expressed musical structure.

Musicians comprehend how to communicate their musical ideas through his/her performance, and as a result, they know that this process is related to the production and manipulation of their sound. Although it is a complex task to determine the phrase boundaries, the musician's purpose is often perceived by others. The word "intention" was the most recurrent term, during the self-report. Concerning question 2 *"Which aspects did you consider to separate the musical phrase when you listened to the recorded takes?"* flutist said, "I felt that here is the end of the idea because I perceived the intention of this musician conducting his phrase". The flutist revealed that he/she recognized the division of the musical phrases thought of the intentional direction and manipulation of sound.

The conduction or organization of phrase expresses the individual perception. Therefore, during the analysis of each flutist, we pointed to the flutists' idiosyncratic interpretation, such as gestural features and the phrasing's choice. During the study about verification and occurrence of gestural coupling in clarinet duets, Mota and colleagues (2014) explained that the musicians' movements contain information related to the interpretative intention of performers.

While analyzing differences in gestural features throughout multiple performances of the same piece, we observed that musicians tended to maintain relatively consistent individual patterns of movement, including both experimental conditions, playing solo and when they were following the others performances. In the next section, we will present a comparison among flutists and discuss the manipulation during solo playing and ensemble playing.

6.1 Comparison of performances

Studies (WANDERLEY, 2002; WANDERLEY et al., 2005; TEIXEIRA et al., 2015) have shown that players' motions were caused by different musical events, such as phrase structure, metrical factors, and key moments in the music. Our results also corroborated with the original proposition, given that during the analysis, we perceived a broad coherence among flutists, considering that performers presented similarities between performed recurrent gestures and organized musical phrases.

Based on this attempt, we confirm that ancillary gestures are not random, given that flutists played the similar shapes in all experimental conditions and takes. Also, we demonstrated

that musicians are conscious about their musical ideas and how to express them through their sound. However, the flutists involved in this research showed that they are not entirely aware of the relationship between their musical phrases and physical motion.

The ancillary gestures also can facilitate the expression of music, examining that they are the so-called phrasing gestures since it is closely connected to musical phrasing (JENSENIUS et al., 2010). These gestures are an integral part of the musicians' performance beyond the stable and reproducible in various performances. It also is important to note that ancillary motions have a communicative function in enhancing the perceivers' experience of musical phrasing.

As previously stated, the grouping of musical ideas in Rossini's excerpt can be communicated in different ways. And each musician can express the same phrase by emphasizing their particular intention. Figure 34 shows the vertical movement of flutists 3 (on the top) and 4 (on the bottom), during a performance of Rossini's excerpt. In the upper part of the figure, we can perceive that the vertical movement of the instrument appears to have a relationship with the excerpt's pulse (triangle marker), and in another one, the motion is related to the rhythmical structure of the piece.

The movement of the both flutists was related to the beat, given that the valley of motion (down of the movement) seems to correspond with the beat tempo. However, the flutist 3's performed small movements during the rhythm figure, dotted eighth-note and sixteenth-note, representing each quarter of the rhythm with flute's motion. These gestures are recurrent in all experimental conditions, inferring the singularity in each interpretation.

In this example, we can observe the intention of each one. It can be related to the individuality of each musician and the way they move in the space, given that the movements tend to be idiosyncratic. In the last example, the gesture can be part of both levels, structural (sense of tempo or rhythm) and interpretative (choice to emphasize aspects of a piece).

Jensenius and colleagues (2010) explain that the vertical movement may help the musician keep track of the tempo, and serve as a signal to other performers, dancers, or listeners perceivers. The authors explain that although such gestures vary considerably between instrumentalists and performance styles, they may be thought of as important for the timing in performance.

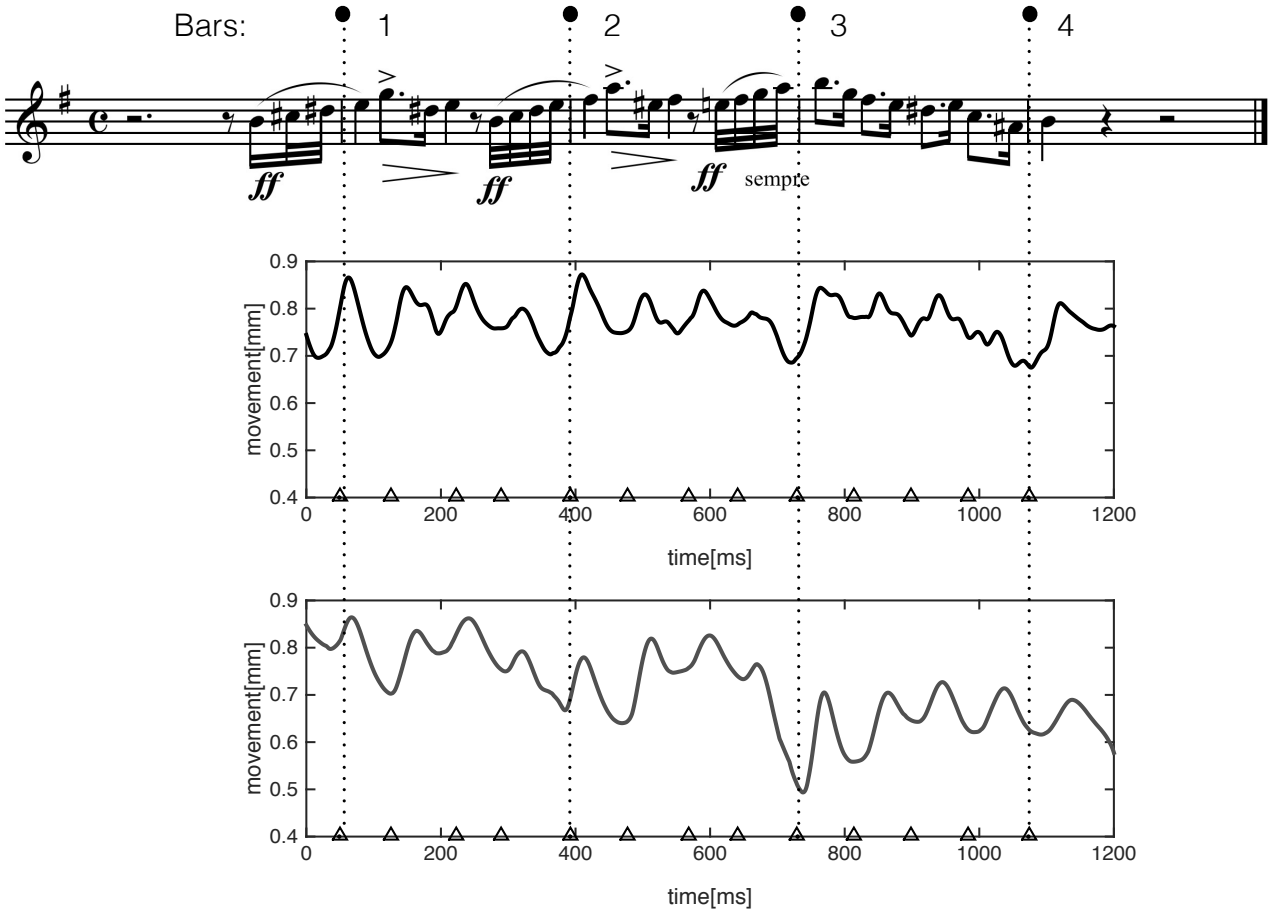

Figure 34 – Comparing time-warped graphs of vertical movement of the flute, during the performance of Rossini's piece. Rows: From top to bottom: flutist 3 and flutist 4. The vertical dashed lines mark the bars, and the triangles indicate the beat.

Another comparison involves flute players 1 and 2 as well as the relation of each one moving in space. Although both flutists performed motion related to the sense of *tempo*, the movement by players is attenuated by the phrasing's motion. As previously mentioned each flutist grouped the notes into their musical idea, flutist 1 arranged notes in small motifs (Figure 35, red lines), while musician 2 organized notes in sub-phrases (Figure 35, green lines). The figure 35 shows the vertical movement in both performances and the inflection of musical phrases.

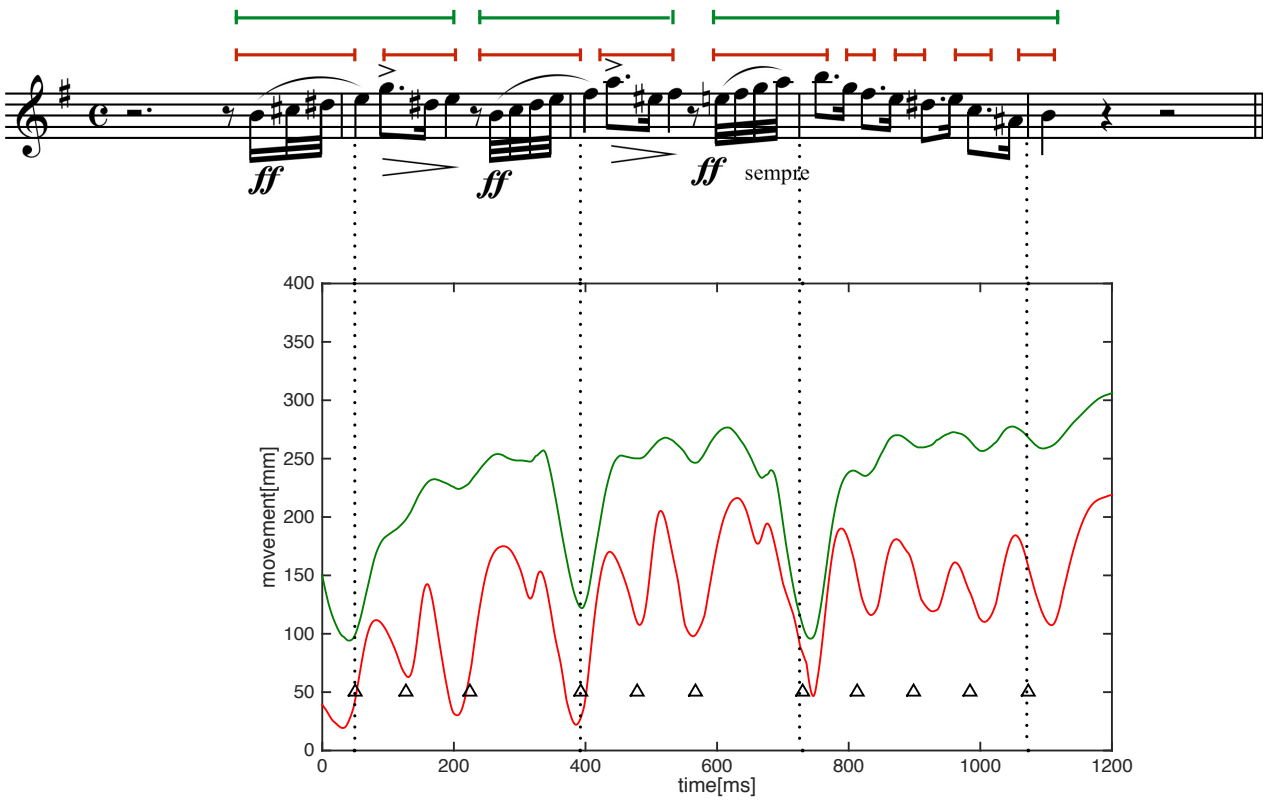

Figure 35 – Comparing time-warped graphs of vertical movement of the flute, during the performance of Rossini's piece. The green curve was performed by flutist 2 and the red curve was performed by. The vertical dashed lines mark the bars, and the triangles indicate the beat. Green (flute player 2) and red (flute player 1) markers on the score represent the grouping of note of each performer.

These findings corroborate the hypotheses of the relationship between physical gestures and musical phrase organization, beyond the idea that the ancillary gestures make part of communicating the musical process. According to Wanderley et al. (2005), the

> performance gesture has become ingrained to the point that it is a feature of solo performance even when coordination with other musicians is not necessary or such movements might facilitate the enjoyment of an attentive audience by providing cues to help observers "perform" mentally along with the solist. (WANDERLEY et al., 2005, p.111)

	Experimental Conditions	Average travel distance of footjoint's flute [m]	% difference
Flutist 1	Playing solo	2.010	
	Playing following the clarinet	2.290	+14%
	Playing following the bassoon	2.068	+3%
Flutist 2	Playing solo	1.367	
	Playing following the clarinet	1.615	+18%
	Playing following the bassoon	1.119	-18%
Flutist 3	Playing solo	1.093	
	Playing following the clarinet	1.201	+10%
	Playing following the bassoon	1.270	+16%
Flutist 4	Playing solo	1.116	
	Playing following the clarinet	1.273	+14%
	Playing following the bassoon	810	-27%

Table 1 – The measurement of distance of footjoint's flute performed by four flutists. All performers except one (flutist 3) moved more during the performances following the clarinet.

6.2 Ensemble Performance

In the analysis of the video recording, it became apparent that the each flutist presented a different manipulation of sound and motion when playing solo and playing in duets. Aiming at identifying the similarities and differences between playing solo and in duets, we measured the travel distance of footjoint's flute across four takes in each experimental condition. The results showed the increase of motion when the flutists played following the clarinet compared with the condition, playing solo. Also, we perceived that occurs a decreasing or maintaining when flute players were following the bassoon (Table 1).

Flutist 3 was the only exception. When questioned during self-report, he stated that due to his experience in an orchestra, the conductor required "precision" during the performance, mainly for the flutist in first flute position. He added that he understood this term as the motion to mark the musical tempo,"in an ensemble, I need to move to express the *tempo* for others". He recognized that the amplitude and quantity of movement depend on the musicians with whom he

is playing. However, he added that when he is playing with another for the first time expresses the *tempo* by moving his body.

In previous research, Wanderley and colleagues (2005) demonstrated that gestures which involve the relation with the rhythmical structure. “Continual movement might be necessary to keep rhythmical features related to both performances and perception intact. A common manifestation of constant motion occurs when a person taps his foot."(WANDERLEY et al., 2005, p.101). Musicians who performed gestures to keep rhythm might be generating continual movement to maintain a sense of time. Player 3 moved the flute in the space more in both duets conditions than solo performances. It makes sense with his report that motion as conduction maintains and communicates the pulse.

Aiming at investigating the relation to increased or decreased motion under different experimental conditions, we observe that the clarinetist performed a huge *rallentando* at the end of the excerpt (figure 36, grey rectangle) and the flutists made an effort to follow him, and consequently, they moved more.

According to Keller (2014), phrase entries and endings present distinct challenges for ensemble coordination. The synchronization at phrase endings is a hard task because tempo may decrease, depending on the performers’ artistic intentions, as phrase boundaries are approached (REPP, 1992). The difficulty can be more, especially if preceded by rest or longer period of silence (Rasch 1988). Phrase boundaries often coincide with structural boundaries that refer to “points of change”. These points are characterized by intense communicative interaction to effect a qualitative transformation in the “feel” of the music.

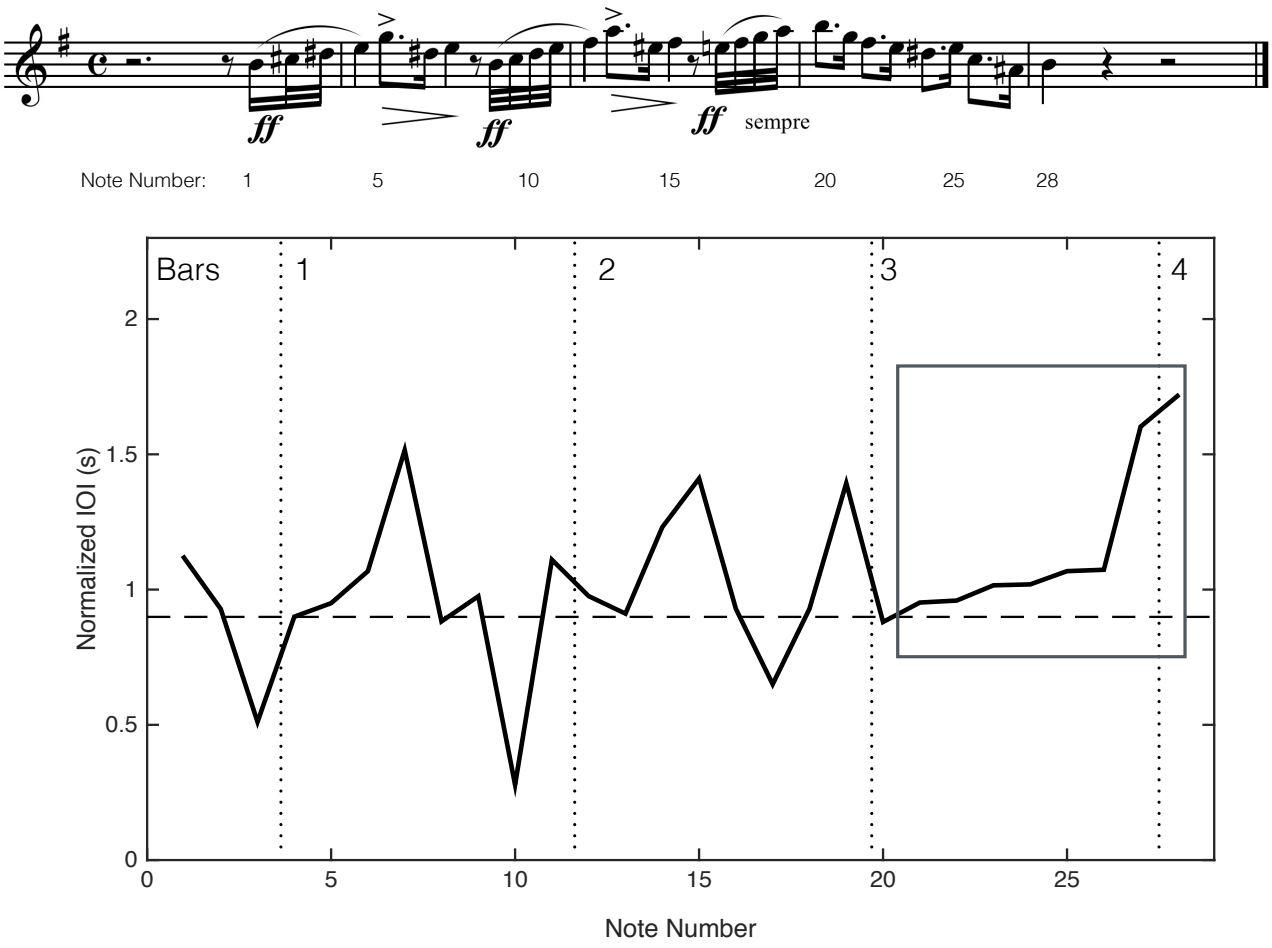

Figure 36 – Note inter-onset intervals for the performances of Rossini's excerpt by the clarinetist. The IOI was normalized to the quarter-note. The horizontal dashed line exhibits the canonical values, and the rectangle shows the last bar.

According to Peter Keller

> Ensemble performers apparently engage in a form of temporal mobilization in preparation for upcoming coordination challenges. Vertical timing deviations may also vary as a function of location within the music's metric structure - specifically, the beat or beat subdivision on which nominally synchronous sounds occur within a bar." (KELLER, 2014, p.265)

Figure 36 shows a significant manipulation over the note durations in the last bar, indicating a large deviation of the IOI curves by the clarinet player. On the other hand, figure 37 shows the evolution of note IOI's along flutist 3's performances in three different conditions: playing solo and playing following the clarinet and following the bassoon. Any deviation from this horizontal line indicates a note duration manipulation by the musician, with upward deviations representing a relatively longer musical note and downward deviations representing a relatively shorter musical note. On top of the figure, there are the flutist 3' solo performances and

after, in the second plot, the tendency of the flutist following the *rallentando* of the clarinetist, and finally the adjustment when he played with bassoon's recording.

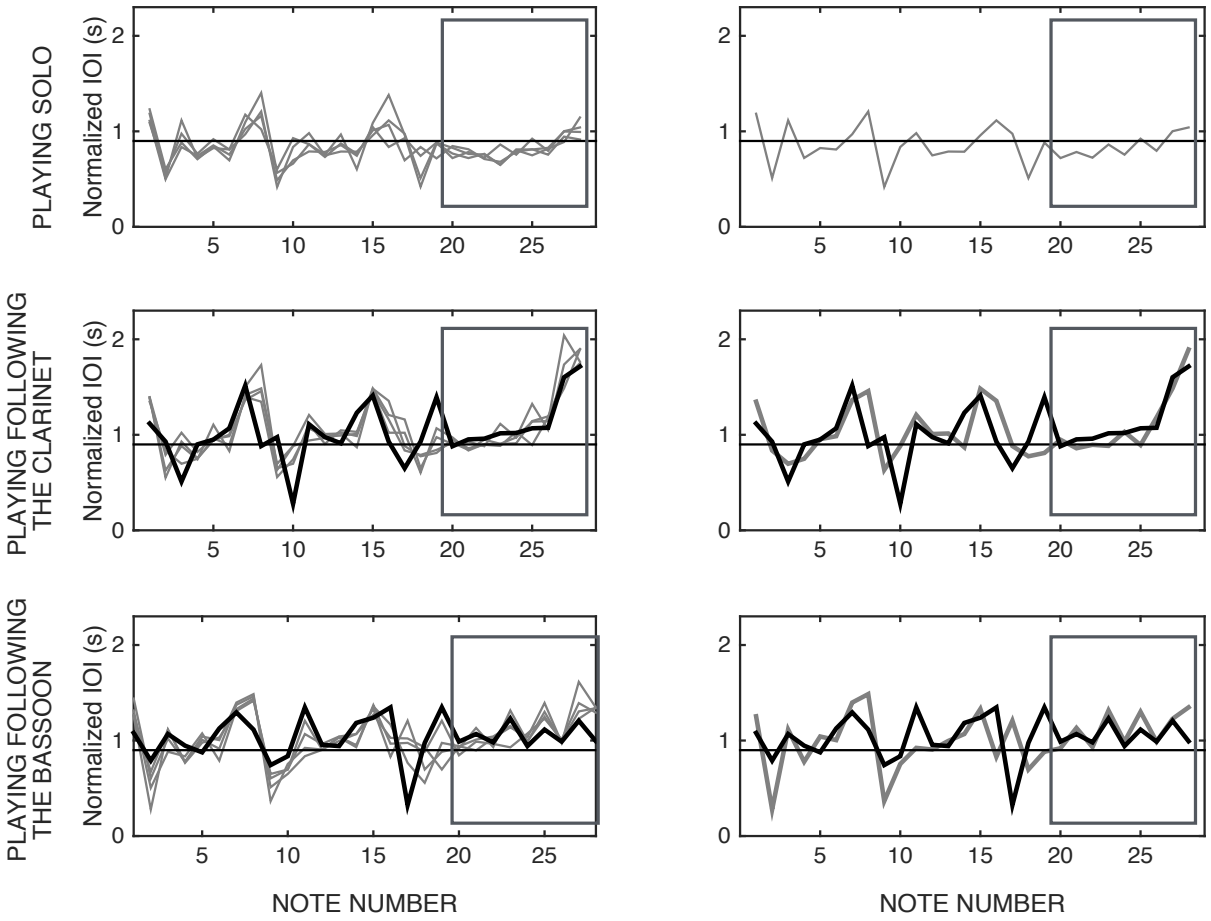

Figure 37 – Note inter-onset-intervals performed by flutist 3 in three experimental conditions. Rows: From top to bottom: playing solo, playing following the clarinet and playing following the bassoon. Columns: Left to right: all take as a motion's profile and only the fourth take. The IOI was normalized to the quarter-note. The horizontal dashed line exhibits the canonical values, and the rectangle shows the last bar.

When we look at the last sub-phrase: accentuated fourth-note, *Thesis*, (notes 20, 22, 24, 26, 28) and punctuated eight-note, *Arsis*, (notes 21, 23, 25, 27), we perceived a profile of a larger *Arsis* in relation of *Thesis*. It can be a demonstration of flutists' intention to group the idea of the upbeat leading to the downbeat. A strategy to emphasize the intervals (*Arsis* and *Thesis*) was to insert pauses between them, causing decreasing the value of the punctuated eighth note.

Figure 37 shows the mentioned profile of the flutist and also the profile of the clarinet and bassoon players. One can see that the bassoonist's profile is similar with the flutist while the clarinetist performed a large *rallentando*. Timing can be affected by the musicians' intention to express structural factors, such as phrase boundaries, metric location, and rhythmic grouping.

Although all players involved listening to a metronome producing a steady beat at 67 bpm, there is a tendency by the clarinetist and bassoonist to play more slowly than flutists during the solo condition. It demonstrates that the choice of *tempo*, in solo condition, was an individual choice. It is important to mention that there was no relationship between the increase of motion and duration (in seconds) of performances.

7 CONCLUSION

The primary objective of this study is to investigate the relationship between ancillary gestures and musical idea organization in different flutists. Players communicate their musical intentions through the manipulation of their sound, and they are conscious of this process. However, the musicians are not aware of the relation between their body's movement and their musical ideas, even if, physical gestures occur during the whole process.

Knowing that ancillary gestures are part of musical communication musicians can reduce gestures but never eliminate them. For this reason, we designed an experiment involving different experimental conditions which enabled changes in musical phrases and consequently, their artistic communication.

We chose a musical excerpt by Gioachino Rossini, played in unison. The performances were analyzed aiming to identify particular ways of grouping musical ideas and the relation with the movement of the performance. We perceived that flutists grouped the excerpt into two different ways: (1) separating musical motifs; and (2) grouping musical motifs. We assumed that in a defined musical motif (upbeat-downbeat) was determinant for the production of the gesture, given that flutists perform recurrent shapes, in all experimental conditions, although, each one emerges an important idiosyncratic ability. It can be because this particular material used by Rossini is strongly recurrent in tonal music and extremely well known by musicians. Additionally, this musical gestures could be produced by physical gestures, as an interactive gesture, influencing or having an effect on each other.

Considering the analysis of Rossini's excerpt, significant relations were observed involving the musical phrase organization and motion. Aiming at identifying how each flutist grouped their ideas, we analyzed the acoustical manipulation following some procedures such as visual observation, analysis of acoustical manipulation, the listening test, and the self-report which each one explained their expressive intentions. These findings point to a complex interrelationship between musicians' gestures and the manipulation of acoustical parameters of which they produce the performer's musical intentions.

Previous studies (WANDERLEY, 2002; WANDERLEY et al., 2005; CARAMIAUX; WANDERLEY; BEVILACQUA, 2012; TEIXEIRA et al., 2015) have already pointed to relations involving the physical gestures and the musical structure. This work also corroborated with them, although we present a study relating to a different instrument. Our findings prove that ancillary movements are not random, given that they are recurrent and stable in all experimental conditions.

Due to the small population observed, we examined each flutist separately as an important factor in determining individual movement and style. Furthermore, we compared them

aiming to understand each interpretation of the same excerpt and, consequently, the motion involved in each one. We also explored the three conditions (playing solo, playing following the clarinet, and playing following the bassoon) and the influence of each flute player throughout the performances.

Future work is needed to elucidate the influence of musicians' work during their performance. Considering the developed skills in each area of knowledge such as, musicians who play in orchestra or small ensemble, flutists who teach in universities, players who work in recording studios, etc.

The work presented here looked for a comprehensive analysis of musicians' motion relating to musical intentions and possible manipulation during different musical interpretations. These assumptions involved the analysis of sound and ancillary body movement. The methodology presented in this study can also be used in other fields, such as human cognition and psycholinguistics. Furthermore, in musicology and future works in music communication, including music as a language, ancillary gestures are the result of the process of musical thinking.

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