Gestures of Body Joints, Musical Pulses and Laban Effort Actions: Towards an Interactive Tool for Music and Dance

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Abstract

In this paper we present a proposal of segmentation and description of gestures of dancers based on the Laban Movement Analysis. This procedure is the main core of an interactive tool for music and dance, implemented in Max/Msp/Jitter and using Kinect, which aims to associate corporal and sonic gestures. The segmentation is done by means of the inspection of the zero-crossings of the acceleration curve of each body joint. After that, different descriptors for each gesture are extracted, and they feed routines to estimate three of the Laban effort factors: time, space and weight. From these data, it is possible to classify the gestures according to the eight basic Laban effort actions. A case study is also presented, in which we search for correlations between the pulse and character of a musical excerpt and the rhythms and qualities of the extracted gestures.

1. Introduction

Recent technologies are responsible for the increasing number of researches and activities dealing with music and movement, a relationship deeply rooted in every human culture. Our research is located at the intersection of three areas: study of the sound gesture, study of the gesture in the context of new sound interfaces and the study of the movement qualities in dance. We propose strategies and tools for the development of interactive musical situations that explore dance and music within the context of electroacoustic composition, live electronic performances and other interactive performances. For this, we started with the investigation of gestures in both artistic modalities, using spectromorphological ideas for the music and motion capture techniques for the dance. We aim to develop strategies of interaction based on the gestural qualities extracted from both domains. In this article, we will focus on the analysis of the gesture in dance, where digital techniques of motion capture, associated with elements from Laban Movement Analysis, are explored with the aim of developing methods of realtime segmentation and description of gestures in dance. We also present a case study: a dancer improvisation based on some excerpts from the ballet Petrushka, by Igor Stravinsky, where we analyze the correlations between musical pulses and characters, body rhythms and the movement qualities.

2. Segmentation and Description of Body Movements

The interaction between sound and body gestures is a fundamental concept in our research. We have chosen to use the term gesture, in agreement with Jensenius et al [1], for we also believe that the ”notion of gesture somehow blurs the distinction between movement and meaning.” Or, as stated by Schacher, ”a gesture is a sequence of movements that form a whole, a gestalt and can be recognized as a semantic unit” [2].

Thus, in extracting and analyzing information from the movements, we are looking for qualitative aspects, and for this we start from theories that aim to clarify the expressive aspects of the movement, such as the Laban Movement Analysis. LMA, as it is known internationally, is a methodology for observing, describing, interpreting and recording human movement and was developed by Rudolf Laban (1897-1958) in the middle of the 20th century. LMA has been employed in several areas such as dance, performing arts, sports, physical therapies, psychology and behavioral sciences. Its methodology is formed by four main categories: Body, Effort, Form and Space. In every movement, all four categories are present, but with different emphasis. For our work, the category of Effort is the most significant, since, according to Laban[3], it is possible to analyze the expressive possibilities of the body in movement through the dynamic qualities of the Effort. According to the Body category, the body can be separated into parts, and each moving part is susceptible of an Effort analysis. Thereby, in our approach, the movement of different joints - digitally captured - have gestural capacities, because they can perform movements with expressive qualities.

Laban proposed four factors of Effort: **a)** Flow - related to the degree of movement control; **b)** Space - related to the trajectory of movement in space; **c)** Weight - related to the resistance to gravity of the movement; **d)** Time - related to the duration of the movement. Each factor can oscillate between two extremes. The flow factor sways between contained and free, the space factor between direct and indirect, the weight factor between strong and light, and the time factor between sustained and sudden. Hence there are two polarities: (1) *Indulging*, with free Flow, indirect Space, light Weight and sustained Time; (2) *Condensing*, with contained Flow, direct Space, strong Weight and sudden Time. Inspired and based on the LMA effort category, we have developed and implemented in Max-Msp-Jitter a real-time tool for the analysis of dancers movements. We found works that adopt a segmentation procedure based on temporal windows, whose lengths may be adjusted manually or automatically [4, 5]. Nevertheless, we opted for segmentation from the positional data of the parts and joints of the body, by delimiting each segment from the observation of the zero-crossings of the acceleration curves. This approach was successfully employed in other works of motion analysis [6, 7, 8].

2.1. Realtime implementation

We extract the 3D position data generated by Kinect for each of the joints of the body. This data is formatted into OSC[1] messages by the Synapse[2] software, and sent to the Max-Msp-Jitter programming environment. Every joint is assigned with a label, which may be accessed as a variable within the implemented patches and subpatches. The reference axes for the torso data are given by the position of the Kinect (called the world reference); the remaining joints use the torso coordinates as reference (called the body reference). From these data, we estimate the scalar velocity of each joint by calculating the Euclidian distance between two consecutive points (its first derivative). The acceleration curve is estimated by the second derivative. The capture rate is 30 frames per second. In order to smooth out spatial and temporal irregularities of the device, we apply a moving average filtering to this data: we use a 2-point filter for the displacement curves, and a 7-point filter for the velocity and acceleration curves. The beginning of each gesture is determined when the acceleration curve exceeds a positive limit (which is adjustable for each joint), and the end of the gesture is defined when the curve returns to the zero value after having reached a negative limit (Figure 1). The speed and acceleration values are calculated with regard to the sample rate, instead of the common unities for time and length.

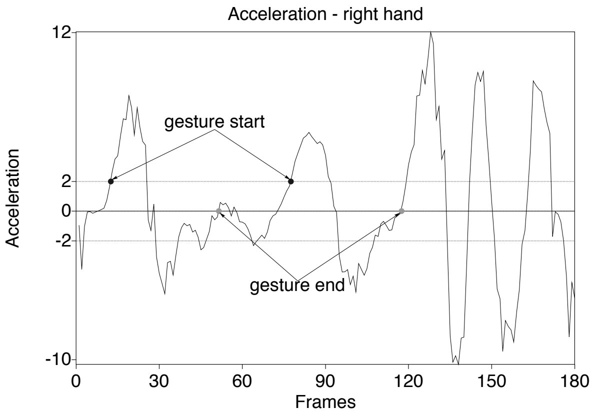

Figure 1: Segmentation of the Right Hand Acceleration Curve with a threshold value 2.

For each segmented gesture we estimate the following descriptors: **a)** dur - duration of the gesture in ms, or the time elapsed between its be-

[1]Open Sound Control (http://opensoundcontrol.org/)
[2]http://synapsekinect.tumblr.com/

ginning and end; **b)** the total displacement in mm made by the joint, which is represented by the integration of the Euclidian distances between every adjacent point; **c)** the displacement modulus, which is the length of the line segment between the start and end points; **d)** the mean speed, calculated as b/a; **e)** l_ratio - the ratio between and b and c; **f)** $\overline{accel}$ - the mean value of the absolute values of every point in the acceleration curve; **g)** a_ratio - the absolute value of the ratio between the positive and negative acceleration mean values; **h)** direction of the gesture on x-axis: $left$ or $right$. It is derived from the difference between the start and end x-values; **i)** direction of the gesture on the y-axis: up or $down$. Calculated as in h; **j)** direction of the gesture on the z-axis: $front$ or $back$. Besides, we also extracted the curve of the torso's floor speed, and other qualifiers based on [9] and [10]: a contraction/expansion index and the distance between different joints, which will not be discussed in this paper.

Figure 2 depicts the flowchart of the implemented segmentation procedure.

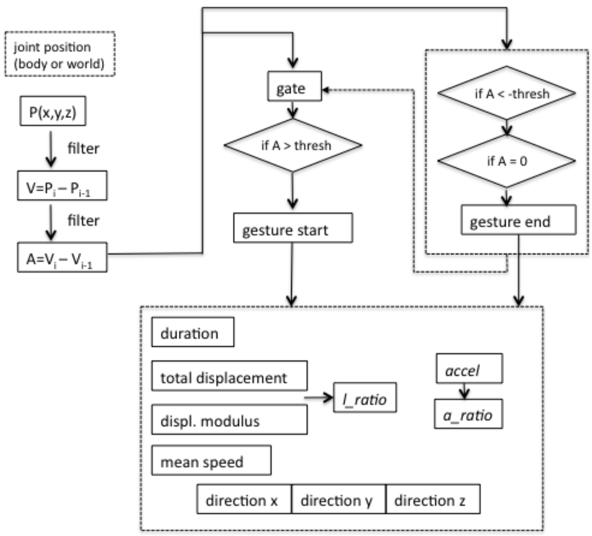

Figure 2: Flowchart of Gesture Segmentation

2.2. Estimating Laban Effort Factors

The combination of these descriptors may help to classify the gestures according to the LMA Efforts factors. We have implemented algorithms to estimate three of them: space, weight and time. We are still working on a good strategy to cope with the flow factor, for it may be applied either to one or to a possibly large set of gestures. As the effort factors are dynamic qualities, it may occur movements in which one or more factors don't have an expressive emphasis, and thus remain latent. Laban [3] considers such movements as incomplete efforts. Based on this conception, we also found useful to define a neutral region between the two poles of each factor.

Factor Space: this factor is directly related to the descriptor *l_ratio*. The more it tends to the value 1, the more the gesture is considered direct. Practical values for the low and high limits of the neutral zone must be defined after much observation, since there is a lot of variation among the different body joints (and also among different individuals).

Condition	Result
l_ratio<low limit	direct
low limit <*l_ratio* <high limit	neutral
l_ratio >high limit	indirect

Table 1: Conditions for the estimation of the Space Effort factor.

Factor Weight: this factor is calculated by means of a logical combination of three descriptors, organized in two conditional queries. Our assumptions are that a strong gesture should oppose gravity (an ascending movement should have more positive acceleration, and a descending one more negative acceleration), and also that a strong gesture should spend more kinetic energy (related to higher acceleration and force values) than a lighter one. Although this algorithm is unable to incorporate important aspects of Laban's weight concept, like the static forces present in very slow or minimal movements, it may contribute to the qualification of faster and wider gestures. The strength factors for each joint were also defined heuristically.

Condition 1: ($a\_ratio > 1$ and direction *up*) or ($a\_ratio < 1$ and direction *down*).

Condition 2: $\overline{accel}$ >strength factor.

Factor Time: we use two descriptors to estimate this gesture quality: the duration of the gesture and the mean value of absolute acceleration. Sudden gestures tend to be not only short but

Condition 1	Condition 2	Result
yes	yes	strong
yes	no	neutral
no	yes	neutral
no	no	light

Table 2: Conditions for the estimation of the Weight Effort factor.

also to spend more energy than sustained ones. Once more, useful values for the duration threshold and for the strength factor must be defined after observation and analysis.

$dur <$ thresh.	$\overline{accel} >$ str. factor	Result
yes	yes	sudden
yes	no	neutral
no	yes	neutral
no	no	sustained

Table 3: Conditions for the estimation of the Time Effort factor.

The LMA defines eight basic effort actions, as depicted in Table 4, which are a combination of the three effort factors just described, excepting the flow (for isolated gestures, the flow factor is strongly correlated with the weight factor).

action	space factor	weight factor	time factor
punch	direct	strong	sudden
dab	direct	light	sudden
press	direct	strong	sustained
glide	direct	light	sustained
slash	indirect	strong	sudden
flick	indirect	light	sudden
wring	indirect	strong	sustained
float	indirect	light	sustained

Table 4: The Eight Basic Effort Actions in LMA.

3. Case Study: Improvising on Excerpts From the Ballet Petrushka

In order to get some insight into the relationships between the pulse and character of the music and the rhythms and qualities of the gestures of a dancer's body, we have chosen some short excerpts from Stravinsky's Petrushka –none of them exceeding 15 s–, which present a clear pulse and also rhythmic and orchestral diversity[3], as depicted in Table 5. A female dancer – an undergraduate student at our university – was asked to improvise freely on each of the excerpts, not long after getting acquainted with them. She was aware of the limitations imposed by Kinect, such as distance, rotation and planes constraints. As mentioned above, we the software Synapse to capture the 3D position data for 15 joints: head, neck, torso, left and right shoulders, elbows, hands, hips, knees and feet. Each rendition was also registered synchronously in audio and video[4]. An excerpt (*strav4*) had its data corrupted and could not be used.

excerpt	rehearsal number	pulse: on score / measured (BPM)
strav0	105	84 / 82
strav1	72	60 / 64
strav2	13	100 / 95
strav3	29	138 / 135
strav5	69	116 / 112
strav6	100	69 / 68
strav7	110-111	112 / 108
strav8	50	76 / 70
strav9	96	138 / 120

Table 5: Chosen excerpts from Stravinsky's Petrushka.

3.1. Results and Discussion

We analyzed the data generated by the procedures of gesture segmentation and qualification in three complementary strategies: a general view of the articulation of gestures with regard to the musical pulses; a quantitative summary of the basic effort actions in each of the renditions; a qualitative approach of the relationship between the musical pulses and the basic effort actions. We also added a neutral basic effort action, defined as a gesture presenting the neutral quality in all three factors.

[3]The rehearsal numbers were taken from the 1912 orchestral score[11]. We used a recording made by the Cleveland Orchestra[12], from which we measured the average pulse.

[4]The videos can be downloaded at http://www.musica.ufmg.br/sfreire/wordpress/.

During (or after) the process of segmentation, it is possible to plot the initial moment and the duration of each gesture in relation to the pulse of the musical excerpt. This display helps to get a general view of the dancer's strategy for the improvisation, as depicted in Figure 3. We have chosen to discuss the excerpt *strav7*, because it has an interesting rhythmic structure, beginning with upbeat and finishing with downbeat chords. The pulses of excerpt have been annotated by manual means (pressing the space tab), intending to approach the dancer's perception of pulse. Initially, we can observe a tendency for starting a gesture following the pulses, as if occupying the silent downbeat: lower limbs (feet and knees) on the fourth and sixth pulses, upper limb gestures (elbows and hands) on the fifth and seventh pulses. Then we observe that the gestures tend to start more freely around the pulses and, at the end –when sound and pulses come together– we observe a search for synchrony expressed by several joints.

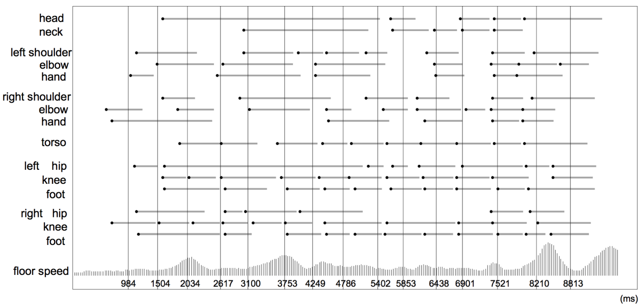

Figure 3: Segmentation of *strav7*.

The extraction of the basic effort actions presented instances of only four actions: punch, glide, slash and float. This means that every strong action is also sudden, and also that every light action is also sustained. Any of them may be direct or indirect. Table 6 presents the amount of each action detected in each rendition. Note that the dancer performed two different renditions of the sixth excerpt.

Despite this marked filtering process (rejecting 70–85% of the total), there still remains many simultaneous (or quasi-) gestures. On average, the number of neutral actions equals that of extreme actions (punch and float), although there exists significant individual deviations. The music in the excerpt *strav8* presents only fast gestures on the piano solo, and was performed by the dancer with a majority of light (float and glide) actions. On the other side, *strav7* and *strav9* have a very rhythmic character, and were performed with a majority of strong (punch and slash) gestures. Excerpt *strav6a* presented the smallest percentage of all effort actions taken together (13.8%), and the second highest percentage of neutral gestures (14.8%). This excerpt has a slow pulse and a explores very low and very high sounds. *Strav5* has a fast pulse, where trumpet and snare-drum have prominency, and was performed with a good amount of indirect and strong actions. Only in *strav6b* we could observe a steady tendency of starting (or ending) an action around the pulse, as Figure 4 shows. We did not find any strict correlation between the start or end points of the actions (taken individually or as a whole) and the musical pulses.

rendition	total	P	G	S	F	N
strav0	116	6	1	8	9	16
strav1	95	11	3	1	5	21
strav2	110	9	5	5	6	7
strav3	62	3	1	7	7	4
strav5	113	8	1	9	11	13
strav6a	101	4	5	2	3	15
strav6b	124	6	8	3	7	15
strav7	124	13	3	9	7	13
strav8	97	5	7	3	10	13
strav9	132	14	3	6	6	28

Table 6: Effort Actions Detected in Each Rendition: (P)ulse, (G)lide, (S)lash, (F)loat, (N)eutral.

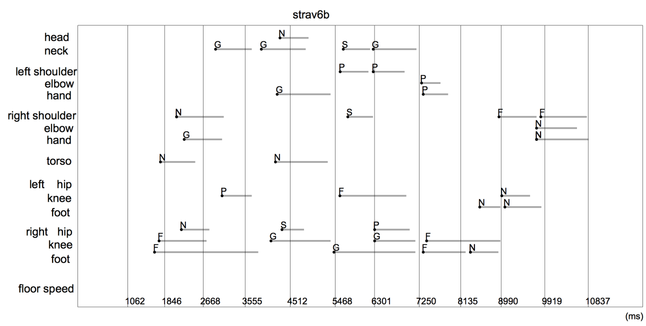

Figure 4: Effort Actions and Musical Pulses in excerpt *strav6b*.

4. Final Remarks

Although our experiment was held with just one individual, it was essential for the development and implementation of tools for extraction and description of body gestures. Next, we must extend this experience to different dancers, and also to request the performance of strong/sustained and light/sudden actions for finer adjustments. As expected, it is very difficult to systematize the relations between musical pulses and the rhythms performed by the joints. Nevertheless, charts like the ones in Figures 3 and 4 may offer a general view of the dancer's strategies for the choreography. Future work points to the association of body gestures with sonic typologies, in interactive situations where dance may control the choice and the timing of sounds. In the mapping strategies, it may not be forgotten that the qualification of a gesture is done only at its end, and that it may be necessary to take in account the immediate past actions. Finally, it must be said that we are not dealing with the desired degree of precision with the setup in use. On one side, the easy access to the required equipment may be an advantage for live performances, which are the main goal of our research; on the other side, the same algorithms could be adapted to more precise setups, when available.

5. Acknowledgments

We thank the funding agencies CNPq, Capes and Fapemig for their financial support for this research project.

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