Sound Body Dance Compositions: An Investigation Through IMU Sensors and Their Effects on Movement Quality

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Abstract. *The Sound Body Dance Compositions: An Investigation Through IMU Sensors and Their Effects on Movement Quality is a field report that presents findings from interactive creative research with Inertial Measurement Units (IMUs), developed by the Núcleo Redes group, using smartphones, smartwatches, and XSens wearable sensors. It discusses how different devices influence movement qualities in dance, grounded in Laban's Movement Analysis System and based on the authors' personal experiences with these IMUs as sound-generating systems.*

1. Introduction

This discussion stems from research conducted by the Nucleo Redes group, coordinated by Daniela Gatti. The group investigates body and movement within creative processes involving multimodal interaction. Over the course of these investigations, several types of sensors have been tested in dance and music creations, including depth cameras and point cloud data, pressure sensors, and Inertial Measurement Units (IMUs). The main goal of this paper is to discuss the use of IMUs as sound-generating systems in dance and to present a field report detailing the differences observed in the dance produced with the use of each IMU-based procedure, drawing on the authors' personal experiences working with these devices. The intention is not to offer a qualitative evaluation, but rather to document and reflect on the movement qualities encountered during the creative processes.

The multimodal research between dance and sensors is varied [1] [2] [3], and has become even more popular due to its potential for creating new realities, both poetic and analytical, for the performative environment. The use of sensors in dance turns creation into a shared process between humans and computers [4]. Also, when sound is integrated as an element of this creative process, like dance and sensors, it can no longer be treated as something separate from the dancer's body. Instead, they become intertwined, offering a physical embodiment of sound. This is what we understand as the Sound Body, as described in [9] .

For this investigation, we chose to work with improvisational contemporary dance, since it is independent of a specific musical structure, in contrast to some popular dances such as samba [5]. Improvisational contemporary dance is known to have a less codified movement pattern [6], characterized by a more fluid and personal structure, which emerges in response to internal and external stimuli and, consequently, varies according to the creative experience of the performer. Therefore, this flexibility enables a co-creative approach with sound, allowing for shifts in qualities and textures in movement and sound that are independent of musical metrics, which proved to be crucial for this study on embodied sound.

To help in the study, we developed movement protocols (consisting of impulse movement, continuous movement, and pauses) that worked as synergistic drivers for the investigations. The IMUs discussed in this work were from smartphones, smartwatches, and XSens wearable sensors, and each of these devices generated distinct bodily and sound-based responses.

The movement protocols mentioned refer to Laban's Movement Analysis System [7], a widely recognized and firmly established system within the contemporary dance community, which forms the basis of our study. Laban describes movement in terms of Body (Which part is moving?), Effort (How is it moving?), Space (Where is it moving?), and Shape (What is the relationship with the environment?). For this research, the movement analysis in relation to the devices focused on the Effort factor, which leads the discussion toward the dynamic and expressive qualities of the gestures.

2. Sensors and Sound Body Movement Analysis

In this work, movement was directly connected to sound, which was generated in real time using IMU data from smartphones, smartwatches, and XSens wearable sensors. The movement-sound relationship varied across devices, and the dance analysis was made individually for each creative process. For all of them, the sound mapping remained the same, based on translating accelerometer and motion data into sound parameters.

The improvisational dance was guided, but not limited, by the three movement protocols that were developed to serve as synergistic drivers for the creative process. These can be listed as follows: A (continuous movement without impulse), B (impulse movement), and C (non-movement).

Each body-device relation led the dance to produce a

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distinct gestural quality, which was analyzed through the lens of Laban's Effort Factor: Space (direct/indirect), Speed (quick/sustained), Weight (heavy/light), and Flow (bound/free). Therefore, the movement protocols can also be examined through the Effort Factor, as a way to clarify how they were developed in accordance with this system:

•A: sustained (speed) / indirect (space) / bound (flow) / light (weight)
•B: quick (speed) / direct and indirect (space) / free (flow) / heavy (weight)
•C: paused, without movement

Moving on to the next topic, the movement analysis has been divided into three sections, each dedicated to reporting on a different dance-sound-IMU creative process.

2.1 Smartphone: MoveGuitar Interface

The procedure with smartphones used the MoveGuitar interface, developed by Jonatas Manzolli. The device was initially created as an interactive model for generative music composition. Through experimentation, it became clear that it could not only interact with existing sounds but also create new ones through movement. As a digital musical instrument, it captured dancers' movements, recording data and generating sound in real time.

The sound generation happened whenever the movement values exceeded a certain threshold, triggering a twelve-note chord stored in memory [4]. During these explorations, we held one smartphone at a time, since this choice provided greater freedom for movements that reached floor level, allowing the use of the free hand for potential support when moving up or down. This interaction is exemplified in figure 1 (image B).

In order to trigger the sound, only protocol B was able to achieve the necessary acceleration. Moments of silence were created through the use of protocols A and C. This factor also extended to the amplitude of the movement, since, due to the system's responsiveness, very small movements were not sufficient to activate sound generation.

On the other hand, during the improvisations we noticed that most of the time only the arm that held the device had this characteristic. This resulted in an interesting work of body segmentation, in which the parts that did not directly generate sound would sometimes remain paused, and at other times engage in sustained yet weighted movements.

Additionally, the dancer was able to select different pitches to change the sound. This increased the interactivity of the research; however, it required the exploration to be occasionally interrupted in order to make such sound adjustments.

Figure 1: Dance improvisation using a Smartphone and movement protocol B

2.2 Smartwatches

The creative process involving smartwatches emerged from a partnership with a project from another institute of the State University of Campinas. One watch was placed on each wrist, but only the device on the dominant hand was used to generate sound. In this process, the sounds were controlled by a third party (another team member), who managed the audio output data via computer, which expanded the possibilities for sound regulation.

These devices have a higher sample rate compared to the smartphones we used before. As a result, in both protocols A and B, the sound was triggered. The C protocol was responsible for ensuring pauses in movement, as well as silent moments.

The authors observed that since the device was attached directly to the body, there was no concern about dropping it, which led to lighter movements and also reduced muscular tension in the cervical region, even during propelled actions. The use of tiny and expressive gestures and the involvement of the torso and lower limbs were less evident compared to the upper limbs.

Additionally, the authors observed a more bilateral participation of the upper limbs, especially in sustained movements, even though only one side could produce sound. This could be analyzed through many perspectives; however, it would require a more focused investigation, which goes beyond the scope of this paper.

Figure 2: Dance improvisation using Smartwatches. C- bilateral movements. D- lighter-weight sustained movements

2.3 XSens DOT Wearable Sensors

The XSens DOT is a lightweight wireless motion tracker [8]. This research used five sensors in total, which could all be used simultaneously as real-time sound generators. These tools had adjustable straps, which allowed the sensors to be attached to various parts of the body, thereby expanding the possibilities for movement investigation.

As with the smartwatches, while using these devices, the sound adjustments and regulations were handled by a third party (another team member). This was the sensor with the highest sample rate investigated so far. As a result, even the smallest movement was capable of triggering sound.

When dancing with this device, movement could therefore have a very small amplitude, which required refined motor precision to perform smaller, yet accurate, gestures in order to obtain a clear sound response. All three protocols were carried out successfully, opening up space for new bodily actions such as shaking (quick/indirect/free/light),sliding (sustained/direct/light/bound), and twisting (sustained/indirect/heavy/bound).

The use of wearable sensors led to new ways of exploring space, with more frequent transitions between different spatial levels (high, medium, and deep), and greater use of different body parts, without the extra muscular tension caused by the worry of accidentally dropping the device. Also, the authors noticed that having more sensors generating sound at the same time caused greater engagement of the entire body structure.

This required more attentive body awareness compared to previous explorations, since there were five distinct sensors distributed on the body, each corresponding to a different sound response, generating a large volume of information.

Figure 3: E- wrist, F- head, G-ankle

3. Discussion

Taking into account the three distinct ways the IMUs interacted with the Sound Body, it is possible to suggest that by understanding how the body moved in each interaction, these movement behaviors can be used as poetic tools in future performative works.

For example, in the case of the interaction with the smartphone, the fact that lighter movements did not trigger sound can be intentionally used as a choreographic strategy, creating moments of silence within the composition. In this case, the dancer could use impulsive movements to activate the triggers and sustained movements to avoid activation. However, this type of exploration limited sound production to the arms or wrists, making the rest of the body an antagonist in this relationship.

The exploration with the smartwatch revealed the possibility of generating sound during sustained movements. This is particularly interesting, as the movement seemed to activate a heightened state of presence, allowing the dancer to consciously choose different body parts to join the exploration of the protocols, apart from the arm that was triggering the sound.

Additionally, it was also observed that this led to less muscular tension and greater bilateral use of the upper limbs. A similar pattern of reduced muscular tension was observed with the other wearable sensor as well, suggesting that not having to hold the device may remove a layer of concern during improvisation.

Therefore, the authors also noticed that as more sensors were introduced, a deeper sense of bodily awareness became necessary to ensure coherence in the performance, with clear movement choices that allowed a meaningful embodiment of sound in real time. This consciousness during performance is necessary to avoid an excess of both sonic and physical information that might otherwise feel disconnected.

The bodily refinement statement in this research stems from the understanding that movement improvisation is not random or merely reactive to sound. Instead, the dancer actively considers the most effective way to establish this dialogue, aiming to create a sense of cohesion that is both articulated with the movement protocols and the expressive poetics that best represent the embodiment of sound through the relationship with the devices.

4. Conclusion

The relationship between the Sound Body and the IMU sensors proved to be distinct for each device. The interaction with smartphones, for example, revealed itself as an excellent way to work with impulsive movements, while also demanding a high degree of muscular control to sustain continuous movement in order to create intentional moments of silence.

With smartwatches, the fact that the device was attached directly to the body significantly reduced muscular tension and encouraged greater use of bilateral movements. Finally, working with multiple XSens DOT wearable sensors required a heightened sense of bodily awareness, as more regions of the body were responsible for generating sound. This demanded careful attention to avoid an overload of both gestural and sonic information.

As observed, each configuration presented valuable possibilities for implementation in a new performative process. With that in mind, we intend to continue working with the sensors to further explore and deepen this interaction.

In future research, the aim is to explore new movement protocols and develop a multimodal performative piece that incorporates new movement qualities and relationships with space and interactivity. When working with dance and real-time sound production through sensors, movement and sound acquire unique qualities, requiring careful attention to the body’s responses to enhance this creative dialogue.

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