LMA driven Dynamic Audiovisuals in a Virtual Reality Live Dance Performance:

Ghostdance

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ABSTRACT

Ghostdance is an evolving generative art project in the field of dance and virtual reality (VR). It mixes visual, auditory and immersive experiences, making use of generative algorithms to create a dynamic audiovisual landscape with continuously changing images and sounds. The performance consists of three interconnected components: a) a duet featuring a human dancer and an avatar mirroring the movements of an absent person; b) the transformation of the physical movements of the human dancer into a visualization of a hybrid body, constantly redefined as a swarm of virtual entities; and c) the sonification of the dancer's movements, introducing an auditory dimension to the exploration of movement.

Performers dance in duets with virtual bodies, with prechoreographed movements, in a visual and auditory landscape that evolves in real time due to adaptive generative algorithms responding to the presence and movements of the performer, informed by pretrained machine learning algorithms able to categorize the quality of the dancer's movement in Laban terms.

CCS CONCEPTS

• ; • **Applied computing** → Arts and humanities; Performing arts; Arts and humanities; Sound and music computing; Arts and humanities; Media arts;

KEYWORDS

Virtual Reality, Dance, Live Performance, Evolutionary audiovisuals

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1 INTRODUCTION

Since its inception, Virtual Reality (VR) has captivated experimental artists keen on exploring its potential to reshape perceptions of the human body, space, and time. While the 1990s saw a surge in VR experimentation within performance art —embodied by artists like the Blast Theory collective [12]— the realm of dance remained relatively reticent in its usage. VR headsets, often viewed as perceptual barriers, limit performers' sensory connection to their environment. Nevertheless, recent advances in VR encourage a shift in perspective, pushing us to break from convention and embrace a new horizon. Meta Quest, HoloLens, and HTC Vive, have thrust it into the mainstream with high-definition headsets and VR-Ready computers delivering real-time, immersive graphics. Fast networks now allow multiple users to share virtual space, and mobile devices offer VR experiences through 360-degree visualization. These developments have reignited interest among artists, questioning whether VR can truly innovate dance. Together with advances on motion capture technologies (mocap), particularly Inertial Measurement Units (IMU), VR is allowing some radical theatrical experience of dance, transforming audience engagement by providing a high degree of immersion in audio-visual spectacles, in imaginary worlds, in transformative spaces blended with reality.

In 2016, "The Tempest" by the Royal Shakespeare Company used IMUs for the real-time animation of a virtual character synchronised with the performance of a live actor, an experience similar to that of the immersive dance pieces "co:lateral" (2016) [14] and "Dökk" (2017) [10], fusing tangible and virtual realities in which the performers are simultaneously on stage and in the virtual environment. "Whist" (2017) [8] brought VR headsets to the audience, allowing them to shape the narrative through gaze-guided interactions, redefining spectator-performer relations. These advancements, blending technology and dance, altered the audience involvement and blurred physical and virtual boundaries. Innovations like 360-degree cameras are also transforming dance experiences. "Nightfall" (2016) placed viewers in a warehouse surrounded by dancers, engaging them directly [7]. "Stuck in the

Middle" (2016) invited viewers to learn choreography, utilizing Go-Pro cameras for immersive perspectives. "Dust" (2017) merged real-world and virtual imagery in a VR setting, allowing audiences to float within performances [2]. Gilles Jobin and Artanim's "VR_I" (2017) immersed participants in virtual environments, interacting with virtual dancers [11]. "Una" (2020) challenged performance space norms, offering individual immersive journeys with sound-enhanced intimacy [15]. These innovations emphasize sound's role in immersive experiences, often overlooked but vital.

From this sample of recent explorations, we can get a highlight of the interplay of realities—body, body-double, images, and sound—in this evolving field.

Ghostdance follows Boidance, a project where we interrogated the synergetic interaction of swarms with dancers in VR [3]. With Ghostdance our aim is to delve into the fundamental essence of physical movement while exploring the possibilities of VR and mocap. What happens when one of the bodies in a duet is physically absent yet visually present? In this project, we have crafted a multimedia performance where a human dancer interacts with "ghostly" entities. This spectral interaction was partially discussed elsewhere [5]. This paper focus on that endeavor and explores the influence of Laban Motion Analysis in the audiovisual spectacle. The performance consists of three interconnected components: a) a duet featuring a human dancer and an avatar mirroring the movements of an absent person; b) the transformation of the physical movements of the human dancer into a visualization of a hybrid body, constantly redefined as a swarm of virtual entities; and c) the sonification of the dancer's movements, introducing an auditory dimension to the exploration of movement.

2 DESCRIPTION

Cecília de Lima choreographed three duet dances performed by Daniel Pirata, Ester Gonçalves, and Miguel Santos, involving extensive rehearsals and motion capture. Using XSens Awinda's inertial sensors in a wearable suit [13], we captured detailed movements of each dancer, recording positions and orientations in 3D space and time. This data was structured into 17 reference points representing body parts within a skeletal framework, then mapped onto 3D avatars to create six distinct scenes, each featuring a single digitized dancer to showcase the choreographed dances. During live performances, dancers wore VR headsets to interact with virtual representations of their absent partners. This immersive experience allowed them to engage with the virtual presence of their partner, visually present but haptically absent. The performer's visual encounter is then shared with the audience via a projection screen, ensuring that the audience can also witness this seamless integration of technology and dance in action.

2.1 The body's pixelated composition

In Ghostdance, we explore the ethereal quality of virtual dancer representations, a concept drawing contrasting views. Steve Dixon, for instance, challenges the idea of an immaterial body in the virtual world, arguing that the transformation of the body in digital environments is essentially a change in the pixelated composition of its recorded or computer-generated image [6]. We focus on the ontological potential of this "pixelated composition," which expands dance-making possibilities beyond conventional limits, as highlighted by Cisneros [4]. This emphasis on the "pixelated composition" is central to the second part of our work.

The second component of our performance involves a visual representation on a secondary screen, depicting in an abstract way the physically present human dancer onstage.

This visual representation was created using Visual Effect Graphs. This is a Unity package providing a node-based visual scripting tool to create composed visual effects made of complex particle systems and shaders. It contains all the necessary data (Graph and Shaders) to run an effect completely. These scripts are compiled by the Content pipeline to generate necessary nested shaders and compute shaders. Our objective was to create the silhouette of the avatar with particles (Figure 1). To implement this visual effect, we began by defining a spawn node that constantly spawns new particles at a set rate (2000 per second). At the initialization of the graph, several nodes are set up to prepare the particle system. First, the "Set velocity random" node is used to assign a random velocity, determining the initial direction and orientation of the particles. Next, the "Set Position (Skinned Mesh)" node is employed to position the particles on the surface of the avatar's mesh. Since the avatar consists of five skinned mesh renderers (head, arms, chest, legs, and feet), this graph requires five instances of the "Set Position (Skinned Mesh)" node, one for each part of the avatar. Additionally, the "Set lifetime" node is utilized to specify how long each particle remains active, influencing effects such as trail length during dance movements. Finally, the "Set color" node is used to define the primary color of the particles.

During the update loop of the graph, further adjustments are made to the particles. The "Update Position" node is responsible for updating the position of each particle in response to the movement of the avatar.

After the update loop, additional modifications are applied to the particles. The "Face camera plane" node ensures that each particle consistently faces the camera, maintaining an optimal visual orientation. Meanwhile, the "Multiply Color over Life" node is used to control changes in particle color over time. Currently, this node adjusts transparency, making particles more transparent as they approach the end of their lifespan. These steps collectively contribute to the dynamic behavior and appearance of the particle system within the avatar's environment.

Any of the above nodes can be editable at any time during play, making it possible to create different effects when the dancer is performing in real time directly influencing its movements based on her postures, rotations, and gestures onstage. As the dancer's actions modify the mesh, the visual landscape undergoes synchronized and dynamic transformations, leading to a distinctive dance collaboration between human and virtual entities. We will explore this synergy further in the subsequent discussion.

2.2 Movement Classification

In our exploration, we employ machine learning techniques to interpret the dancer's movements using Laban Movement Analysis (LMA). Contemporary dance is a vast canvas encompassing an array of movements, extending beyond traditional steps to encompass gestures from everyday life, sports, and even animal behavior.

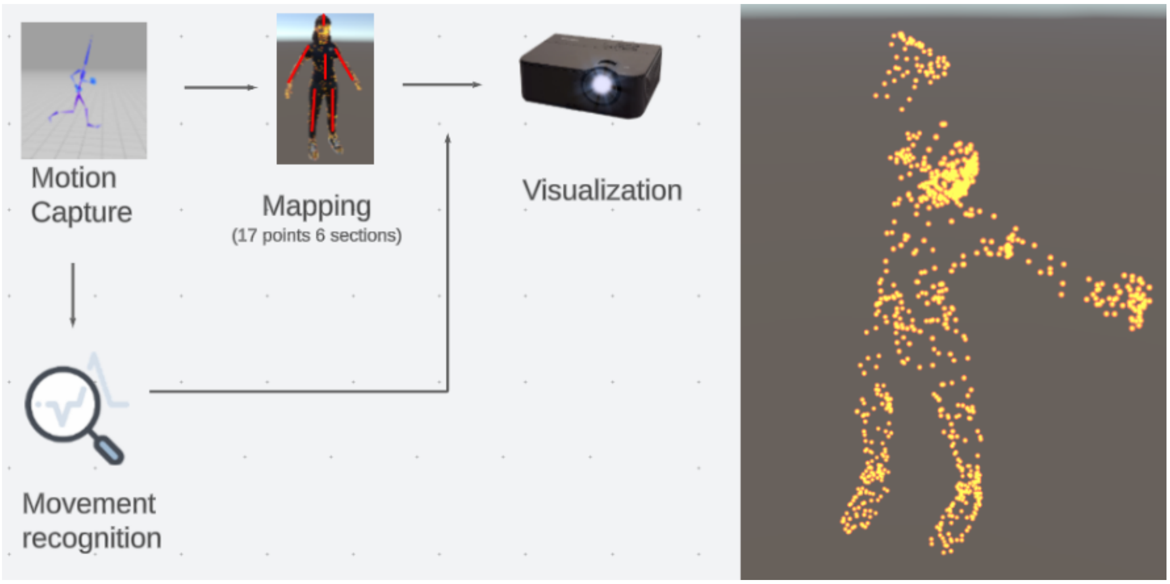

Figure 1: The body of the performer is visualized as particles.

Analyzing this diverse spectrum of movement is a formidable task, a field pioneered by Rudolf Laban and further developed by Irmgard Bartenieff [1]. Laban Movement Analysis focuses on Body, Space, Effort, and Shape, with Effort comprising Weight, Spatial relation, Time, and Flow, culminating in eight fundamental "Action Drives": Punch, Slash, Dab, Flick, Press, Wring, Glide, and Float.

These eight actions form the basis for our AI training via machine learning. We have developed a Deep Learning Neural Network, called Long Short-Term Memory (LSTM), which was trained to recognize these 8 classes of movement actions present in a dataset of 1350 movements. Movement interpretation based on Laban's principles influences parameter weights governing the rules defining particle's behavior. For instance: A punch is a movement that can be described as being direct in space, strong in weight, and sudden in time. Taking these features into consideration when a movement is classified by the AI model as "punch", then we can adjust the particles color to a reddish tone.

This fusion of human and machine performance is showcased through large-screen video projections. One projection reveals the dancer's perspective within the virtual world, while the other presents dynamic scenes with manipulated swarm parameters, including behaviors, colors, and shapes, creating a captivating blend of dancer and living swarm entity for viewers.

2.3 Immersive Audio

The immersive audiovisual experience of the show is enhanced by an audio design resembling a sonic cloud, with multiple audio sound waves blended together to create a unified auditory experience. This audio-mixing process involves adjusting the levels, frequencies, and spatial positioning of individual audio elements (Figure 2). To manipulate the sound properties of each of the audio elements, we use a FAUST Plugin integrated into Unity3D. FAUST is a versatile programming language for sound synthesis and processing [9].

The avatar is divided into 6 objects: head, chest, right arm, left arm, right leg, and left leg, each with different Faust models attached to them. Each audio element occupies a certain range of frequencies within the audible spectrum with its own unique characteristics in terms of frequency range, dynamics, and spatial positioning. The wave will continuously play, even during periods of no movement.

The performer's movements are analyzed using the machine learning module resulting in a Laban's action drive classification. Unity will then translate the received classifications into values readable by Faust. For this, we use a parameter constraint table with the actions and associated range of values. Depending on the recognized action, distinct values will be transmitted to the objects linked to each limb, changing their waves in term of their frequency, amplitude, and envelope.

As a result, for instance, the directness, strongness and suddenness produced by a body moving with a "punch" quality will be materialized in a corresponding quality change in the overall sound being produced. Each sonic element will dynamically reflect the spatial changes produced in the associated body segment, enhanced with the values relative to its "punchness" coming from the table changing its volume and frequency.

In addition to volume and frequency balance, spatial positioning plays a crucial role within the stereo or surround sound field. By placing elements at different points in the stereo field, we create a sense of space, depth, and movement within the mix.

3 DISCUSSION

Our exploration revolves around the interplay of dancing within physical and virtual realms, which raises profound questions about the intersection of technology and art, the art of sound manipulation, the role of movement in audio composition, and the impact of these innovative techniques on the audience's sensory and artistic

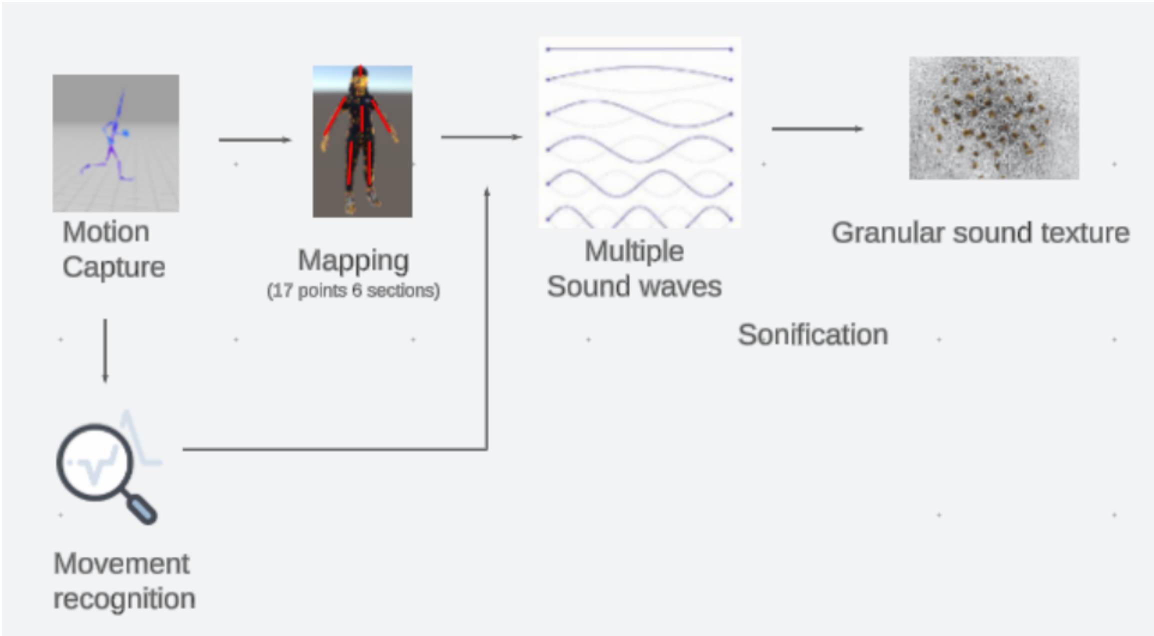

Figure 2: The sound module.

experience. At the heart of this performance lie three computational domains: motion capture, machine learning and real time audiovisuals. The audiovisual texture within the "Ghostdance" performance is dynamic and ever-evolving, responding in real-time to the performer's movements and interactions.

The positioning of i) granular particles on the surface skin of the visual performer and ii) audio elements within the stereo field is intimately influenced by the performer's actions, with the panning and spatial distribution of audio elements, creating a spatially immersive audio experience that harmonizes with the visual elements. This spatial dimension adds depth and dimension to the auditory experience, complementing the visual aspects of the performance.

The use of a versatile programming language like FAUST offers a high degree of precision and adaptability for individual sound grains. FAUST can be adjusted on the fly to synchronize with the performer's movements or the visual elements, ensuring a seamless integration of audio and performance. The performer's movements, analyzed by the Laban classification module, directly influence the behavior of sound elements, altering parameters such as frequency, amplitude and envelope characteristics. This dynamic response forges a real-time and interactive connection between the performer's physical actions and the audio component. Changes in the audio texture correspond to actions or behaviors of the visual appearance, enhancing the cohesion between auditory and visual elements, creating a multisensory experience for the audience. For example, when the swarm changes direction or speed, the sound adapts in real-time. This feedback loop strengthens the visual-aural connection, creating a 3D auditory experience that complements the visual depth of the performance. The dynamic and evolving nature of this interaction fosters a sense of unity between the visual, auditory, and kinesthetic elements of the performance, keeping it fresh and engaging. The audience becomes attuned to the connection between the performer's actions and the evolving soundscapes, inviting them to actively observe and interpret this relationship. The unpredictability and constant evolution of these elements introduce an element of surprise and excitement, ultimately adding a sense of liveliness that keeps the audience engaged and intrigued.

4 CONCLUSIONS

We have discussed Ghostdance, an evolving immersive performance combining technology and digital art. This work in progress explores the dynamic interplay between the physical and virtual domains, where dancers interact with virtual avatars of their duet partners in a virtual reality setting. Audiences bear witness to this fusion, enhanced by a constantly evolving soundscape, as the live dancer engages with the digital void, blurring the boundaries between realities. The synergy between the human dancer and the algorithm infuses the visual performance with unpredictability and dynamism. This symbiotic connection encourages contemplation on the ever-shifting lines between the real and the virtual.

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