Ghostdance: Evolving soundscapes in an Immersive Virtual Reality Experience

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Abstract

“Ghostdance” is an innovative ongoing work in progress of generative art that explores the captivating blend of visual, auditory and immersive experiences in the realm of virtual reality (VR). This project harnesses the potential of generative algorithms to create a dynamic soundscape that continually transforms, inviting participants on a journey through ever-changing abstract and visual soundscapes. In the immersive VR experience, participants are transported to an environment where the auditory field evolves in real time, thanks to central generative algorithms that continually adapt and reshape the experience. Ghostdance's generative algorithms respond to the user's presence and action, detecting the properties of their movement, as defined in Laban terms. Each user embarks on a unique and unpredictable visual and auditory adventure, actively influencing the evolution of the environment through their movements and interactions in the virtual space.

Ghostdance takes its name from a research project on dance in virtual reality [9]. It challenges the traditional boundaries between art forms, blurring the line between composition and improvisation. As performers move through the VR environment, they not only witness the harmonious fusion of sound and images, but also actively co-create the evolving composition.

1. Introduction

Since its arrival in the 1980s, Virtual Reality (VR) technology has captured the imaginations of experimental artists who were keen to explore its potential to reshape perceptions of the human body, space and time. The nineties saw a surge of experimental use of VR in the field of performance art, exemplified by artists such as Eduardo Kac and the Blast Theory collective.

When performance incorporates virtual reality (VR) and dance, several questions arise. Aesthetics, the creative processes behind the performance, the physicality of the performances, the relation between the VR environment and the physical movements of the dancers, are only a few of the aspects the new technology calls into question.

Surprisingly, the world of dance has largely remained an uncharted area in the context of VR.

Although one can ponder the reasons behind this relative absence, traditional dance performances, known for their profound physical dialogues between performers, possess a unique depth and richness. VR headsets, often seen as a perceptual barrier, impose limits on the performer's sensory connection to their immediate environment. However, VR challenges us to see dance through a different lens, encouraging us to break free from convention and explore new frontiers.

Recent advances in VR technology have brought it into mainstream use, with such products as the Meta Quest, HoloLens and HTC Vive offering high-definition headsets and powerful VR-ready computers that deliver high-quality, immersive, real-time graphics. In addition, fast network technology now allows several users sharing the same virtual space, and cell phones have become platforms for VR experiences, thanks to 360-degree viewing techniques. Such developments have sparked renewed interest among artists and content creators, raising the question of whether VR has the potential to bring something truly new to dance itself.

With "Ghostdance", our aim is to delve into the fundamental nature of physical movement. What happens when one of the performing bodies in a duet is not physically present? As part of this project, we have conceived a multimedia performance in which a human dancer interacts with "ghostly" entities, and this article focuses on this effort. The public performance consists of three intertwined components: a) a duet featuring a human dancer and an avatar that mimics the movements of an absent person; b) the transformation of the human dancer's body movement into the visualization of a hybrid body, continually being redefined as a swarm of virtual entities; and c) the sonification of the dancer's movements, adding an auditory dimension to the exploration of movement.

2. State of the art

Virtual Reality (VR) technology was initially designed to create artificial environments so convincing that human cognition interprets them as real. By VR we mean a computer-generated three-dimensional environment that a person can explore and interact with in a real or physical way, using special electronic devices such as a headset with internal screens or gloves equipped with sensors. This person enters this virtual space or lands in this environment and, while there, is able to manage objects or perform a series of actions. VR artificially creates sensory experiences that can include sight, hearing, touch and vision. Despite this filtering of the human essence to generate perceptual and emotional responses, it manages to immerse users in a simulated world relatively successfully. How does this perceptual trick affect performance?

Since its inception in 1980, VR has been a playground for innovative artists, each of whom has explored its creative potential in a variety of ways and with a variety of approaches (360º footage/computer-generated environments, many/one solo artists, different approaches to the role of the audience, etc.). For example, Brenda Laurel's film "Placeholder" uses VR to manipulate the audience's perception, allowing viewers to feel the world through the eyes of various animals and birds, offering a very unique sensory encounter [16]. VR has also been used for socio-political commentary, such as "Desert Rain" by the British collective Blast Theory, which looks at the virtualization of reality, particularly in the context of the disinterested and “playful” nature of modern warfare [13].

In recent years, VR technology has become more accessible to a wider consumer base, giving rise to numerous creative initiatives, including in the field of dance. One example is the Dutch Opera's VR ballet "Nightfall", a 360-degree experience using stereoscopic cameras and quadraphonic audio [7]. EU-funded research projects such as WhoLoDancE [22], Moving Digits [18] and BlackBox [3] have also contributed to this growing visibility and interest. Pieces such as "Giselle VR" [20], "Stuck in the Middle" and "Man A" [8] blur the boundaries between spectators and performers, actively involving the audience in the show. Google Labs teamed up with the Martha Graham dance company to explore motion capture and environments created with TiltBrush (which allows volumetric drawings to be edited) [24]. One of the captivating aspects of VR is the way it defies the constraints of the traditional space-time of the stage. In "VR_I", Gilles Jobin challenges the conventional scenography by transforming the virtual actors into giants or tiny elements on the virtual stage, reformulating the traditional concept of spatiality [12]. "Dust", a collaboration between Andrej Boleslavský, Mária Júdová and choreographer Patricia Okenwa, immerses the audience in the presence of dancers, allowing them to transform into floating dust particles that interact with the performers [2].

The combination of VR, 3D and artificial intelligence makes it possible to transform the perception of space and objects in the virtual world, providing them with dynamism and some level of intelligence. Works such as "Virtual Reality on 5 Dollars a Day" [15] and "Barcode Hotel" display dynamic interactions between objects, the audience and the performers [11]. In "Boidance", Caporal et al. allowed the dancer to dive into a dynamic landscape and interact with a swarm of graphical elements [4].

Although there have been numerous experiments in the field of VR and dance, there is still a relative scarcity of development in the field of VR and sound in the context of VR dance performances (as illustrated in the overviews of the field, for example in Sophie Smith [21]).

3. Description

Three duets were choreographed by Cecília de Lima, with the participation of dancers Miguel Santos, Ester Gonçalves and Daniel Marchão. These duets were the subject of exhaustive rehearsals, with countless repetitions to perfect their execution. After these rehearsals, we used motion capture techniques to record the precise movements of each dancer.

Using a wearable motion capture device, specifically a suit equipped with inertial sensors from XSens Awinda [23], we obtained a digitized representation of a dancer, capturing their movements with detailed information about positions and orientations at each moment or frame. The movements were converted into a comprehensive set of 17 reference points, discerning the exact positions and orientations of various body parts, including the head, spine, limbs, arms and legs, within 3D space in time. This data is structured hierarchically, mimicking the kinematics of the body within a skeletal structure. This information was then associated with a visual representation, which was eventually mapped onto 3D avatars (Fig.1).

These dancing avatars were then used to create six different 3D scenes, each with a single digitized dancer to perform the choreographed dances.

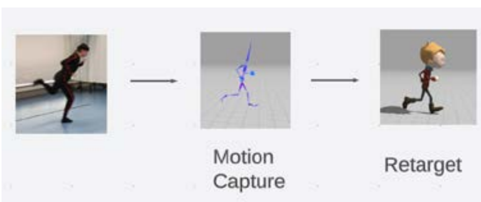

Fig. 1. Motion capture allows us to retarget the movement from a human to a virtual character.

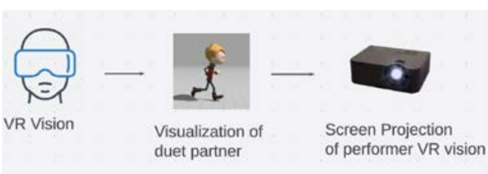

Fig. 2. The audience witnesses the performer's point of view.

For the live performance, we invite the dancers to put on VR headsets and perform the choreographed dance. Through the VR headsets, they can see the duet pair as a 3D representation, replicating the movements of the missing duet partner.

In the immersive VR environment, the human dancer is presented with the other half of the duet, visually present but tactilely absent. This unique perspective allows them to interact with a virtual representation of their partner.

This visual experience of the performer is then shared with the audience via a projection screen, ensuring that the audience can also witness this fusion of technology and dance in action (Fig. 2).

3.1 The body swarm

In Ghostdance we investigate the ghostly nature of the virtual representation of the dancers, but some authors such as Steve Dixon dispute this idea of the immaterial body in the virtual environment. "When the body is transformed... in digital environments, it is not an actual transformation of the body, but the pixelated composition of its recorded or computer-generated image" [6, p.212]. In this work, we aim precisely at the ontological potential offered by this "pixelated composition", or as Cisneros puts it: "Avatars offer the user a variety of choices that do not exist with the living body ... expanding the conventional ways of doing dance." [5, p.17]

This fact is highlighted in the second part of the work. The second element of the show revolves around the visual representation on a second screen, capturing and transforming the movements of the human dancer physically on the stage. To bring this visual element to life, we used a swarm of geometric figures to represent the dancer.

Swarm Behavior is an algorithmic technique that allows us to emulate the behaviors observed in nature, such as the grouping patterns of fish, insects, and birds. In this virtual space, a swarm made up of graphic elements reacts to the artist's movements and gestures throughout his performance.

The swarm's behavior emerges from the interactions of the individual elements that make it up. In 1987, Reynolds introduced "Boids", an algorithm designed to simulate biological swarms [19]. This concept is based on three fundamental rules:

1. Separation rule: Avoid clustering and collisions with the closest members.
2. Alignment rule: Move in the direction of the group's average heading.
3. Cohesion: Converge towards the center of mass (average position of the group).

The movements of the dancer's body directly influence the behavior of the swarm. Each of the 17 points obtained from the motion capture process, which defines the dancer's body, corresponds to an element of the swarm. Consequently, the postures, rotations, accelerations and gestures of the performer on stage have a continuous impact on the actions of the swarm, which strives to maintain balance.

In the absence of external influences, the swarms tend to reach a state of near equilibrium, producing repetitive but subtly varied patterns. However, when the performer enters this virtual environment, her actions disturb this balance, inciting dynamic responses from the swarm's elements.

As a result, the visual landscape is dynamically transformed, guided by the self-organized behaviour of the swarm elements, which synchronize their movements with those of the performer. This symbiotic interaction results in a distinct and constantly evolving dance collaboration between the human dancer and the virtual swarm (Fig. 3).

3.2 Movement analysis

In addition, we use machine learning techniques to decode the dancer's movements using Laban Movement Analysis (LMA).

Contemporary dance encompasses a wide range of movements, covering not only traditional dance steps, but also gestures from everyday life, sport and even animal behavior. Analyzing such diverse movement possibilities is a formidable challenge, a field initiated by Rudolf Laban and perfected by Irmgard Bartenieff [1][10].

The structure of Laban's Movement Analysis consists of four key components: Body, Space, Effort and Form, which intertwine to create phrases and relationships. The Effort component, in particular, comprises four critical factors: Weight (light or heavy), Spatial relationship (direct or indirect movement), Time (sustained or sudden), and Flow (free or bound) [17].

The combination of these factors in space, time and weight leads to what Laban calls the "action impulse", which encompasses eight fundamental actions: Punch, Cut, Dab, Flick, Press, Twist, Slide and Float. These eight basic actions serve as the basis for our

Artificial Intelligence training through Machine Learning.

This interpretation of movement according to Laban influences the variable weights of the parameters that govern the rules that define the swarm's behaviour. As the algorithm translates the movement into LMA, this interpretation adjusts the parameter weights for the attraction, separation and orientation rules that shape the swarm's behaviour. Since the three simultaneous rules of interaction that guide the swarm's behaviour have specific weights, influenced by Laban's characterisation:

Direct to indirect movement affects the Alignment weight. • Heaviness to lightness influences the Separation weight.

Sudden to sustained movement impacts the Cohesion weight.

Consequently, the swarm is shaped mainly by the dancer's movements, with each point recorded by the motion capture device being considered part of the group of virtual boids. It is also influenced by the Laban interpretation of the movement performed (Fig.3).

The audience experiences this fusion of human and machine performance through two large-screen video projections. In one of them, the dancer's point of view is seen as he immerses himself in the virtual world. In the second projection, the entire scene unfolds, with dynamic camera angles and manipulation of the swarm's parameters, including behaviours, colours, shapes, and sounds. This thought-provoking performance leads viewers to consider whether they are watching a dancer or a live swarm.

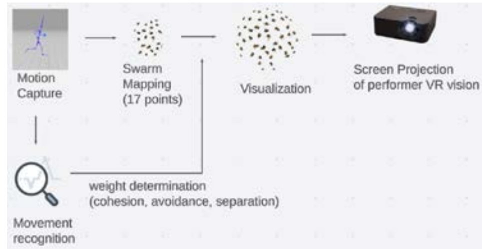

Fig. 3. The body of the performer is visualized as a swarm with 17 reference points of his body mapped as members of a larger group.

3.3 Immersive Audio

The third element that contributes to the audiovisual experience of the show is immersive audio. Unlike conventional sound generated by modulating sine waves in the Fourier tradition, the auditory component of this show is a mass of sound - a sonic cloud, so to speak. It can best be described as a real-time composition in which sound is transformed into a granular texture. This process begins with an existing piece of music (in this case, the 1981 song "Ghosts" by Japan), which is broken down into small fragments, each lasting just a few milliseconds.

Starting with the original sound file of the original song, this is read into a buffer. Next, a random segment of the sound file is chosen for granulation. Once this reference area has been defined, the whole process is confined to its boundaries. These fragments are further divided into 40 small segments, each lasting 10 milliseconds, called "grains", which are then assigned to the dynamic elements of a swarm, allowing each grain to be positioned in the stereo field. This link between the granular sounds and the swarm particles results in a dynamic and constantly evolving audio texture, moulded by the spatial arrangement of the swarm elements. To manipulate the sound properties of these individual grains, a FAUST plugin integrated into the Unity3D platform is used. FAUST, which stands for Functional Audio Stream, is a versatile programming language designed for sound synthesis and audio processing. It provides a wide range of capabilities in audio and music production, including sound synthesis, audio effects and signal processing. This versatility allows for precise control of every grain.

The interpreter's movements are analysed using Laban's classification module, which provides data on its direction, weight and speed. These factors influence the movement of the grain pointer through the selected region. The weight of the movement determines the transverse speed of the grains. A slower movement leads to a slower movement of the reading pointer and vice versa for a light movement.

During moments of immobility when no movement is detected, the pointer remains fixed at a specific point, causing the sound grain to repeat continuously.

The volumetric shape of the swarm, defined by the area of the bounding box, alters the length and amplitude of the grain envelope. Depending on their position within the swarm, the sound grains can have different audio envelopes. These envelopes can take the form of simple curves, rectangles, or slopes on both sides at an angle of 45 degrees. Closer to the centre of the swarm, the envelope looks rectangular. In a secondary radius area, the sides of the envelope become slanted at an angle of 45 degrees, and, beyond these two areas, the original curve is maintained.

Sudden movements affect the transversal direction. When the pointer reaches the end of the region selection, it typically jumps back to the opposite end. However, when two sudden movements are detected in sequence, the transversal direction shifts. The pointer may change its direction depending on the current orientation.

The overall directness of movement determines the grain rate, or how quickly grains are produced. If a grain is produced before the previous grain's envelope ends, they overlap and accumulate. The time between the start of one grain and the start of the next is known as the grain onset, measured in grains per second.

This system generates a rich and ever-evolving audio environment, creating a dynamic soundscape that enhances the immersive experience of the performance.

4 Discussion

We are exploring the relationship between dance in simultaneous physical and virtual environments and this work raises questions about the crossroads of technology and art, the nature of sound manipulation, the role of movement in audio composition and the impact of such innovative techniques on the audience's sensory and artistic experience.

Granular synthesis creates a complex and textured soundscape. It introduces numerous tiny grains of sound, each with its own unique characteristics, resulting in a rich and intricate aural environment.

The texture in the Ghostdance performance is dynamic and constantly evolving, changing in real time based on the artist's movements and interactions with the swarm's behaviour. The positioning of the sound grains in the stereo field is influenced by the behaviour of the swarm and the actions of the performer. The position and movement of the swarm elements are closely linked to the spatial positioning of the sound grains. As the swarm elements move in virtual space, they trigger the panning and spatial distribution of the sound grains. This synchronisation creates a spatially immersive audio experience that aligns with the visual elements. This spatial dimension adds depth and dimension to the listening experience, creating a sense of movement and space that complements the visual aspects of the performance.

Using a versatile programming language like FAUST provides a high degree of precision and control over the individual grains of the sound. FAUST's versatility extends to real-time adaptation. The composition adjusts in real time to respond to the performer's movements or the swarm's behaviour. This adaptability ensures that the audio remains strongly integrated into the performance, increasing the overall artistic impact.

The performer's movements, as analysed by the Laban classification module, directly affect the behaviour of the sound grains. The direction, weight and speed of the movements are translated into changes in the transverse rate of the grains, the onset of the grains and the parameters of the grain envelope. This dynamic response creates an interactive, real-time link between the performer's physical actions and the audio component.

Changes in the audio texture correspond to actions or behaviours of the visual swarm. This synchronisation of the sound environment and the visual representation of the swarm increases the cohesion between the auditory and visual aspects, creating a multi-sensory experience for the audience. For example, when the elements of the swarm change direction or speed, the sound can also adapt in real time. This feedback loop reinforces the visual-auditory connection, making the show seem more integrated and interactive. As the swarm moves, the sound can shift in stereo space, creating a 3D auditory experience that complements the visual depth of the performance. The dynamic and evolving nature creates a sense of unity between the visual, auditory, and kinaesthetic aspects of the show, an interaction that keeps the show fresh and engaging. The audience becomes aware of the connection between the performer's actions and the evolving soundscapes, encouraging audience members to actively observe and interpret this relationship. The unpredictability and constant evolution of the two elements adds a sense of liveliness and surprise.

5 Conclusions

We presented "GhostDance", a work-in-progress immersive performance driven by cutting-edge technology. This is a work in progress that explores new artistic possibilities and raises profound questions relating to the nature of digital art. It does so by delving into the interaction between the physical and digital realms. The dancers perform physically while simultaneously engaging with virtual avatars of their duet partners in a virtual reality environment.

The audience witnesses the interaction between the physical and digital elements. This immersion is further enriched by the audio environment, which includes sound granulation and real-time manipulation. The audience, in the midst of a constantly evolving auditory landscape, observes the live, flesh-and-blood dancer on stage, clumsily interacting with the void, perceiving through the screens an overlapping of realities that interact with digital entities. This coexistence between the tangible and the virtual, amplified using swarm behaviour and algorithmic elements, introduces an unpredictable and dynamic dimension to the visual performance. This dynamic creates a symbiotic link between the human dancer and the digital swarm, thus prompting reflections on the boundaries between reality and virtuality.

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