Design and Evaluation of a Hybrid Reality Performance

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ABSTRACT

In this paper we introduce a multimodal platform for Hybrid Reality live performances: by means of non-invasive Virtual Reality technology, we developed a system to present artists and interactive virtual objects in audio/visual choreographies on the same real stage. These choreographies could include spectators too, providing them with the possibility to directly modify the scene and its audio/visual features. We also introduce the first interactive performance staged with this technology, in which an electronic musician played live five tracks manipulating the 3D projected visuals. As questionnaires have been distributed after the show, in the last part of this work we discuss the analysis of collected data, underlining positive and negative aspects of the proposed experience.

This paper belongs together with a performance proposal called *Dissonance*, in which two performers exploit the platform to create a progressive soundtrack along with the exploration of an interactive virtual environment.

Keywords

Interactive Performance, Hybrid Choreographies, Virtual Reality, Music Control

1. INTRODUCTION

Influences from different disciplines strongly characterize contemporary art production, where theatre, dance, visual art and music often combine together to form novel artistic expressions. One of the resulting consequences of this wonderful process is the difficulty in making a neat distinction between interactive/real time performances and participatory installations; although previously separated, these two experiences merge, as the technical and conceptual arrangement of novel art pieces - the mise en scène - binds audience and performers with a powerful emotional stream.

More and more often technology is the basis of these changes, affecting the nature of the stage itself, blending paradigms, and extending the performance range with undiscovered expressive possibilities. Johannes Birringer defined the "digital dispositif" [2] as the comprehensive environment which conveys this extended notion of the stage, a platform where different media and data are captured and networked to define a dialogue between performers, audience and the "dispositif" itself. Birringer argues that "the imaginative range/freedom [of the performance] is to some extent driven or inspired by the arrangement that are made [in the digital dispositif]", but he adds that, at the same time, certain methodological restrictions or limitations may arise from the defined platform behavior.

The work presented throughout this paper stems from our interest in technology supporting art, especially concerning the way interactive multimodal setups could support innovative ways of expression, without interfering with the creative process. To this end we designed and developed a multimodal platform for Hybrid Reality live performances: exploiting 3D projection and motion capture technologies, artists and interactive virtual objects share the same real stage, creating choreographies where real and virtual world literally overlap. The created 3D environment embraces the spectators too, providing them with the possibility to directly modify the scene and its audio/visual features.

In Section 3 we discuss technical and conceptual details that define a Hybrid Reality performance, describing the guidelines we followed to transform our Virtual Reality (VR) room into a mixed-reality stage. In Section 4 we introduce *Virtual_Real*, the first audio/visual performance that took place in this complex environment; in this part the specific creative process is analyzed, exploring the technical and artistic solutions that characterized the performance as an interactive audio/visual concert. As questionnaires have been distributed after the show, in Section 5 collected data are presented, in order to perform an evaluation of the audience's experience, both from the perceptive and the emotional point of view.

2. RELATED WORKS

The primary characteristic of this project is the co-existence on the stage of a human element (i.e. one or more performers) and a machine element (i.e. the "dispositif"), which manifests itself through the interactive visual environment (Figure 1); both actors play in the scene, sharing the attention of the spectators in a duet which might enhance the expressive power of the piece. This concept has already been explored in impressive works. With *Glow* [4] the company Chunky Move presented a piece in which a dancer moved while lying on the ground, surrounded by a digital landscape generated in real-time in response to the performer's movement; the tracked body's gestures are extended by and in turn manipulate the video world that surrounds it, ren-

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dering no two performances exactly the same. In Miwa Matreyek's *Glorious Visions* [12] the performer's shadow is projected onto a screen where an oneiric world comes to life, transforming her body into the center of gravity for small living creatures. Although in this case the "dispositif" is technologically rather simple, the result is highly absorbing and surreal. Low cost technologies networked with code-based frameworks are also exploited in the project *Euphorie* [1], a cross between a sonic installation and a musical gig; the performers play self-made instruments behind a transparent screen, where real time visuals were displayed.

Figure 1: The performer on stage, surrounded by the virtual environment: the lava planet follows his movements, always floating over his palm.

The second characteristic of our multimodal platform consists of the possibility to influence sound and music through the manipulation of the graphic environment, exploiting visuals as a new kind of musical instrument; this concept has inspired artists and researchers, and involved different experimentations on human-computer interaction technology. In *The Sound of One Hand* [8] Jaron Lanier performed live on a plain stage, wearing a head-mounted display and a single dataglove: immersed in a dramatic virtual environment he could play different kinds of virtual musical instruments, while his viewpoint was projected onto big screens for the benefit of the audience. Other wonderful examples are the *Iamascope* [5], by Fels et al., and the *Manual Input Sessions* performance [9], by Levin et al.: in these works hand gestures are tracked to mutate the projected graphic environment, and to dynamically create and control sounds.

The third characteristic of the platform is the active role the audience has during the performance. Since the beginning of the 60's art boundaries have broadened to embrace the participation of the audience; Allan Kaprow's *Happenings* [7] are the first examples of such an attitude, breaking down fixed structures and hierarchies that previously differentiated a performance from an installation. More recently technology and consumer electronics have been exploited to create participatory environments, as in the *Dialtones* [10] performance, again by Levin at al. In the works of Kaiser et al. [6] and Samberget al. [14] the possibility to improve the interaction between the VJ and the audience in dance clubs is investigated, thanks to a multimodal console accessible from the dance floor; while in *The Interactive Dance Club* [15] Ulyate et al. proposed a wonderful venue where 9 installations located all over the club permitted participants to influence music, lighting, and projected imagery, in zones for single participants, dual participants and groups.

3. DESIGN OF A HYBRID REALITY PERFORMANCE

3.1 Projections and Viewpoint

In order to achieve a consistent superimposition of virtual and real elements within the scene, we have made use of the technical setup available inside our department VR room, where a $4x2m^2$ Powerwall is in front of a $4x4m^2$ area. Here 12 IR cameras and an inertial ultrasonic tracking system can be exploited to track people and objects. Two 3D projectors synchronized with shutter glasses draw virtual objects, which appear to move off from the flat surface of the screen, invading the physical space in front of it.

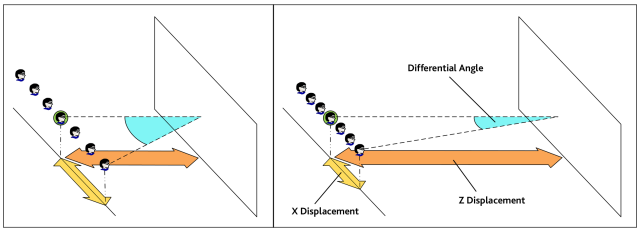

Figure 2: Increasing Z displacement (shown in dark orange in the schema) and diminishing X displacement (in light orange) we succeeded in reducing the differential angle (in blue) between the fixed center viewpoint and the actual spectators' viewpoints; a lower angle determines less visual distortion for side spectators.

This environment has been previously used only to perform single user experiments, to evaluate perception and interaction paradigms in virtual environments. Several observations of subjects interacting with virtual objects raised the idea to stage performances where interaction could be transformed into artistic expression, shown from the viewpoint of spectators that watch the artist while in the virtual environment. Thus we decided to discard from our system one of the essential features of projected VR, user's head tracking, together with the concept of user's viewpoint. We defined instead a fixed central viewpoint, shared among all the spectators and ideated to fit the position of a sitting person, who directly watches the screen from the audience's seats. Generally a shared viewpoint introduces an error in the correct perception of 3D objects, a distortion, especially during interactions; this error consists of a misalignment between the perceived vanishing points of the two superimposed scenes, the real one and the virtual one; its intensity is directly proportional to the X displacement between the fixed viewpoint and the audience viewpoint, while it considerably diminishes with increasing Z displacement, that is the distance from the virtual scene (Figure 2). Despite the extremely small space available in our VR room, we succeeded in creating an area where up to 9 spectators can comfortably take a seat and attend a performance with no noticeable visual distortions (Figure 3).

Thanks to this arrangement, in the eyes of the audience performers, real items and virtual object share the same physical space, on a stage where interaction discloses an infinite number of choreographic possibilities. According to Milgram's Taxonomy and Virtuality Continuum [13], we chose the term "Hybrid Reality" to define these performances, since real world and virtual world objects coexist, and "real physical objects in the user's environment play a role in (or interfere with) the computer generated scene". Nevertheless this definition doesn't completely fit the kind of arrangement we are presenting in this paper, in fact, as

Figure 3: Despite the small available space, the chosen arrangement permits to host up to nine spectators in our VR room.

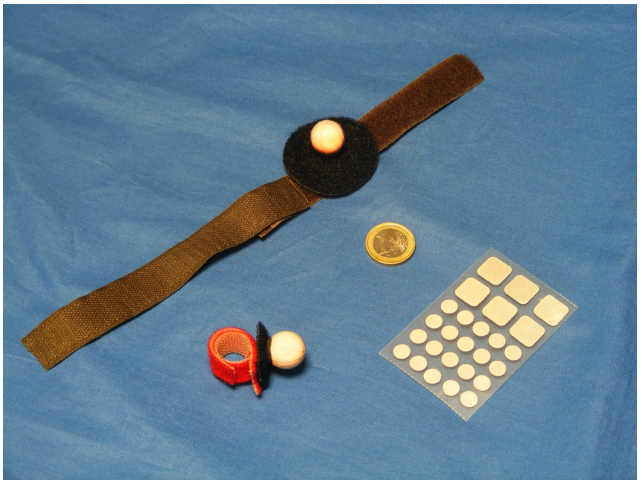

Figure 4: Small passive reflective markers tracked by the system: the adhesive version (on the right) does not need Velcro strap to be attached.

happened in similar performances like Kim Vincs and John McCormick's *Touching space* [16], the environment loses its egocentric connotation, becoming exocentric, separating the viewer from the user that actually interacts with virtual (and real) objects.

3.2 Hybrid Choreographies

As the overall arrangement loses its VR connotation, projected 3D images become a natural evolution of live stage visuals, not only accompanying the artist during the show, but embracing her/him. The complete arbitrariness in shape, position and behavior of these projected objects drastically enlarges the choreographic possibilities of Hybrid Reality performances, with respect to bi-dimensional visuals we are used to. Furthermore the brain of the "dispositif" that manages the virtual environment and all of its rules can be programmed, in order to lead all of these features into a meaningful relationship with the on-stage artists (i.e. Hybrid Choreographies).

Most of this work is developed in VRMedia[1] XVR, the central software on our platform. Primarily meant for VR application design, it proved to be a very flexible environment, thanks to a simple but powerful code syntax, and to the possibility to support custom cross-language modules (e.g. C++ dll's, Python scripts). External meshes, modeled with 3D graphic softwares like Autodesk[2] 3DStudio Max or Maya, can be imported into the virtual environment, including materials and animations; making use of GLSL scripts, these objects can be manipulated in real time, dynamically changing material properties and model geometry through fragment and vector shaders. Also physical behavior can be simulated, exploiting the Nvidia[3] PhysX module to give life to the environment, allowing the creation of worlds governed by real or unnatural physics laws.

XVR also processes and routes huge quantities of data coming and going from and to external hardware and software. Each device used on and off stage can be connected to this network, in order to synchronize it with the whole system, and to easily define its role within the performance. Such a client-server structure, easy to expand and to configure, has been already included in other live performances setups, like Last Man to Die's *Vital LMTD*[11].

[1]http://vrmedia.it/
[2]http://usa.autodesk.com/
[3]http://www.nvidia.com/

One of the most important sources of data within the platform is the low-latency IR tracking system, which broadcasts the positions of up to 50 passive reflective markers (Figure 4) moving within the stage area; thanks to the UDP connection between the built-in client and the main server, these data are stored and processed by XVR. These lightweight markers can be easily attached to the performer's body, in different configurations, to distinguish specific parts of the anatomy (e.g. hands, legs, head). In a 3D controllable environment, providing the system with information about artists in space, such as body pose or finger XYZ position, is fundamental to make virtual objects responsive to performer's movement, to make them communicate (directly or remotely) with other real and virtual subjects [3]: objects could move according to dancers' position in improvised choreographies, or they could be dragged directly by their hands, shattered or manipulated into new shapes (Figure 5). Furthermore tracking is not confined to humans, items that are physically located on the stage could carry markers and be utilized to trigger virtual interactions.

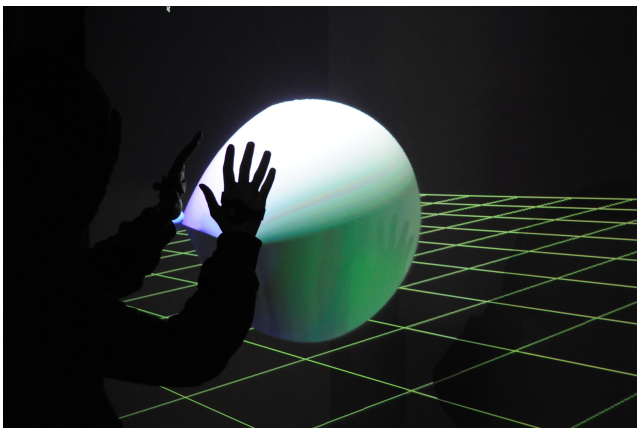

Figure 5: Through manipulation the performer can directly affect the shape of meshes, creating in real time unrealistic figures.

One of the most interesting features supported by our platform is the possibility to bi-univocally bind the visual and the sound environment: OSC and MIDI signals are sent and received through the network to exchange infor-

mation with softwares for audio synthesis and processing, external controllers and musical instruments. Sound is outputted onto a custom 14.1 audio system for sound spatialization, while external audio signals are acquired through a 26 in/out low latency audio interface. This scenario permits a real-time 3D visualization of music, programmable according to the preferred synaesthetic criteria. Moreover, in terms of interaction, it provides on and off-stage performers with the opportunity to manipulate sounds and music not only playing their musical instruments and controllers, but also physically interfering with the virtual environment; practically an infinite number of different metaphors can be created, using body motion capture as gestural input to control all the sound devices connected to the network, and providing visual and audio feedbacks both for performers and audience.

3.3 Audience's Participation

Tracking is also used to offer spectators an active role in the hybrid performance. To provide collaborative experience the audience's gesture recognition does not need to be as sensitive and precise as that of the performer; however a good resolution surely helps in distinguishing single spectator's different motions and intentions, allowing participation in a more engaging manner. Diverse solutions can be employed to achieve this goal according to the desired level of detail, even using two different systems on the same platform, one to monitor the stage, the other to monitor the seat area.

We successfully tested 2D silhouette extraction through a single RGB/IR camera and 3D volume reconstruction with a time-of-flight IR sensor, both working with no marker support needed. Because of the small dimensions of our VR room, we were also able to enlarge the detection area of the 12 IR camera tracking system used for the stage, extending marker detection up to the seat area; although heavily linked to the morphology of the place, this third solution proved to be convenient in terms of latency, resolution and technical ease, as no additional devices have been plugged into the system. Furthermore we strongly believe that a high sense of immersion - of inclusion - within the performance could be achieved permitting the single spectator to directly touch virtual objects, thus modifying the audio/visual environment. In a Hybrid Reality performance the presence of graphic elements is perceived as real, for they occupy a volume in a space that is real, and they support interaction with a real performer; so, as these objects travel through space getting closer, spectators look forward to reach them, to touch them, expecting to have interaction capabilities themselves. 3D tracking of spectators' hands allows the extension of interaction algorithms to audience's participation (including metaphors for sound creation as well), in order to create a collaborative multimodal domain, where the communal possibility to touch/modify the virtual environment works as a connection between the artists and the audience. This connection may be subjected to well defined rules, to highlight the artist and her/his starring role as opposed to spectators, or it may discard such a distinction, moving on the blurred line that divides performances from installations.

4. VIRTUAL_REAL

Virtual_Real has been the first Hybrid Reality performance designed and developed for our multimodal platform. Born from the collaboration with the electronic composer USELESS_IDEA[4], the performance stemmed from the artist's passion for both music and graphics as expressive means, which were combined together to transform a music concert into an experimental audio/video venue.

The on-stage setup was rather simple: in front of the screen we centered a table over which the performer installed his gear, consisting of a laptop, an USB MIDI controller and a small mixer, connected to the platform; the incoming audio signal produced by the musician was processed through Ableton[5] Live, extended with the LiveAPI/ LiveOSC package. The off-stage setup, although much more complex, was completely transparent to spectators, and included an Intersense[6] 3D wand, a Monome[7] (Figure 6), and the previously introduced multi-camera motion capture system. The performer also had a marker attached with a strip over his dominant hand; spectators were provided with a marker as well, mounted on a small ring to be put on top of their index finger.

Figure 6: A 3D wand and a 40h Monome assembled from a kit were plugged into the system as off-stage audio/visual controllers.

USELESS_IDEA played five original tracks, specifically composed for the event. Each track was associated to an immersive 3D choreography, arousing visual atmospheres directly connected to the sounds and the music. The artist actively participated in all the steps leading up to the final show, trying to explain his motivations and his messages, towards a keen refinement of algorithms, controls and contents. With the artist's agreement, we chose to alternate 3D visuals with short 2D sequences, in order to intensify the perceptive and emotional impact of virtual objects, as well as to gently blend in the eyes of the audience the classic paradigms of stage visuals with the unconventional immersive experience. Particular effort was put onto interaction design too: many algorithms were tested by the artist in order to define a set of simple but also powerful and visually impressive metaphors, to process sound manipulating the 3D visuals; consequently the musical pieces have been composed as modular structures, which encourage the building of live improvisation for visual interaction.

The result looked like a journey in five different scenarios, from deep space, to worlds of dancing and pulsing particle systems, where the artist could move objects as 3D XYZ faders, and trigger loops by touching and morphing unnatural shapes. Spectators were also engaged by this

[4]http://uselessidea.blogspot.com/

[5]http://www.ableton.com/

[6]http://www.intersense.com/

[7]http://monome.org/

journey (Figure 7): each object coming close enough to be reached supported interaction, as it could be moved, thrust aside, and sometimes manipulated in its visual characteristics (e.g. color, shape) according to the current scene rules. The related sonic manipulation has been limited to sound spatialization of some audio patterns, as the artist insisted on keeping the venue as similar as possible to a live concert, where music is exclusively played by the performer. Just behind the audience, an off-stage performer supported the artist, triggering scene changes and manually controlling some parameters of visual choreographies, utilizing the Monome and the wand plugged into the network.

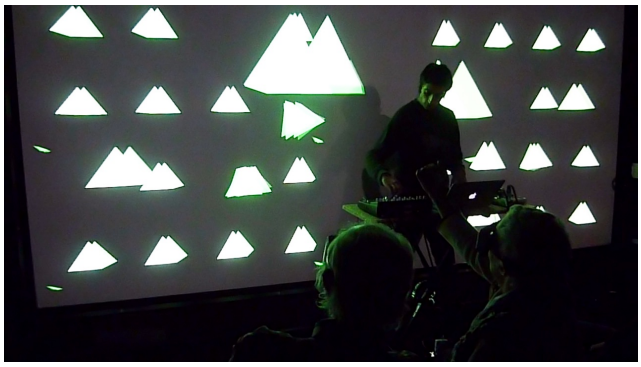

Figure 7: A shot from the performance: in the bottom right corner it is possible to see a spectator stretching his arm for interacting with the projected 3D particle system. When watched through shutter glasses the flat stereo projection is perceived as moving towards the audience.

5. EVALUATION

5.1 Questionnaires

Virtual_Real took place three times, allowing a total of 27 spectators to attend the show. We exploited the venues to give the audience a questionnaire, in order to collect data about the different aspects of the performance, as they experienced it. The questionnaire explored 5 specific evaluation areas; the first area, "General Evaluation", investigated the perceived similarity with other audio/visual performances previously attended by the audience. The second area was called "Perception", and dealt with the extent to which spectators perceived depth in 3D projections as opposed to 2D contents, while "Presence" area addressed interaction and immersion, including the sense of participation. In the "Transparency" area the global comprehensibility of the performance and the relation between artist's gestures and audio/visual output were investigated. The last area, "Specific Evaluation", dealt with the communicative role of 3D visuals, also compared to 2D sequences.

A total of 24 sentences (called also items) have been extracted from these 5 areas, and inserted into the questionnaire in a shuffled order; each sentence stated an observation regarding the related evaluation area. After the show spectators were asked to answer to what extent they agreed or disagreed with the sentences, choosing a number between 1 (completely disagree) and 7 (completely agree). Acquired data were then analyzed, focusing on central tendency, through median, mode and mean extraction, and on dispersion, calculating range across quartiles and standard deviation. In order to avoid predictable biases linked to the common astonishment generally felt during the first VR experience, before each show the audience attended a short training: a virtual environment was presented, in which each spectator had to complete some interactive tasks, touching and moving objects with head tracking and motion capture support.

Item score analysis showed amazingly positive results, which included most of the five evaluation areas (Figure 8); in particular remarkable results came from "Specific Evaluation", where almost the totality of the items scored median and mode values equal to 7: for example we can report that the 59% of the audience completely agreed saying that the sequences containing 3D visuals enhanced their involvement in the performance (S13). This item produced a median equal to 7.0, with a lower quartile equal to 6. Similar data (median equal to 7.0, lower quartile equal to 5) were extracted by the item stating "I preferred objects to come out from the screen" (S20), which was scored 7 by the 67% of the audience. Other items regarding the expressive power of visual interaction ("which helped to understand the artist's message", S9), the sense of participation to the performance (S7), and the perception of a world that grew "far beyond the physical boundaries of the room" (S17), scored very high median and mode values (6 or higher), less stunning results because of slightly stronger dispersion (e.g. mode percentage less than 50%), but extremely positive overall.

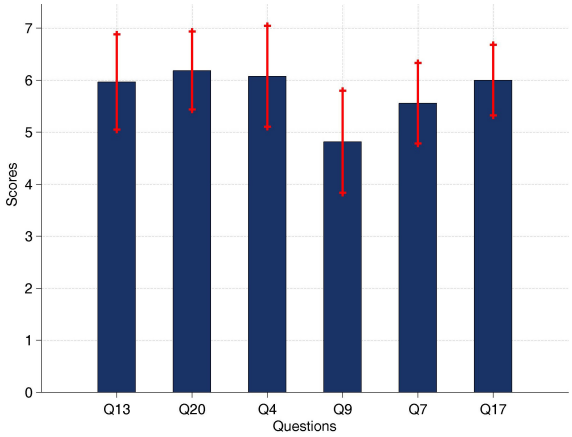

Figure 8: The graph shows in blue the mean value and in red the standard deviation value of each sentence level of agreement score. Sentences number 13, 20 and 9 come from "Specific Evaluation" area, 4 and 17 from "Perception" area, and sentence number 7 from "Presence" area.

In the last page of the questionnaire some blank space has been left to encourage spectators to leave comments, which turned out to be a very useful source of information. As expected, almost all comments were positive, remarking on spectators' astonishment and enjoyment already deduced from data analysis; some spectators also left interesting observations about features and aspects they liked the least during the performance, including important suggestions that could work to improve the proposed experience. Some spectators complained about the difficulty of understanding when audience interaction was available, as few parts of the choreography supported it, with limited effects over the environment; they agreed with the suggestion that more frequent and powerful interaction paradigms could spectacularly increase audience involvement. Others highlighted that whenever the 3D projections reached the borders of the screen or hit the body of the performer, sudden visual paradoxes temporarily interrupted the stereoscopic effect; they suggested using larger screens, taking extreme care that virtual objects never overlap with real stage elements.

5.2 Artist's Feedback

As the presented technology aims at supporting and inspiring artists and art production, we also invited the performer to write down comments and impressions, in order to understand to what extent he could exploit the platform as a strong communicative means.

Since the beginning of the collaboration USELESS_IDEA has been fascinated by the entanglement between the real and the virtual environment available on our platform. Furthermore the possibility to create an interaction, a dialogue, between these two worlds stimulated the artist to experiment new ways to communicate with the audience: mourning about the opacity and unclearness electronic music performances commonly suffer from, he underlined the expressive power of visual interaction, and the direct cause-and-effect relation caught by the audience. This brand new possibility strongly influenced the composition process too, opening new horizons for live composition and improvisation.

Two negative aspects were underlined: the lack of tactile feedback when handling virtual objects, and the disparity between performer's perspective and the projected viewpoint. According to artist's thoughts, these issues could invalidate the expressiveness of visual interaction choreographies, negatively influencing the overall result of the show; however, he added that, as for other common challenges in the domain of live performances, rehearsal sessions and a good support from technical team easily prevent these negative effects.

6. CONCLUSIONS AND FUTURE WORK

With this paper we presented a multimodal platform ideated to stage a novel kind of performances, called Hybrid Reality performances; thanks to VR technology, in the eyes of the audience artists are immersed within a 3D reactive environment, interacting with virtual objects to affect graphics and sounds. We named Hybrid Choreographies the set of rules that defines, for each performance, the meaningful relationship between artists' gestures and the surrounding audio/visual environment. These choreographies could include spectators' participation too, providing them with the possibility to transform each venue in a unique collaborative experience.

Theater, dance and music could be performed and even blended on this platform, to open the path to unpredictable artistic productions. The first example of Hybrid Reality performance was called *Virtual_Real*, and took place in our VR room as an interactive audio/visual concert; held by the electronic musician USELESS_IDEA, the show featured five music tracks, performed together with five Hybrid Choreographies, during which the artist created music both with real instruments and through virtual environment interaction.

After the show spectators were provided with a questionnaire, in order to collect data about the different aspects of the performance. Data analysis and comments from both the audience and the performer revealed a strong enthusiasm towards the platform capabilities, which really encourages us to continue artistic experimentation in Hybrid Reality environments. Thanks to these feedbacks we are now focusing on the use of dynamic shared viewpoints to provide also the artist with a meaningful visual feedback, and transparent screen technology to avoid virtual content occlusion.

To confirm these positive results, obtained in a well controlled technological environment, we are interested in moving on more conventional stages, like theatres and concert halls, through a portable setup complementary with local equipment and its infrastructure. Operating in this scenario would extend the possibility to attend the show to a much bigger number of spectators, in an environment exclusively ideated to host artistic performances. According to this necessity we are going to actively participate to NIME conference, performing live a Hybrid Reality music piece in which two performers create a progressive soundtrack along with the exploration of an interactive virtual environment.

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