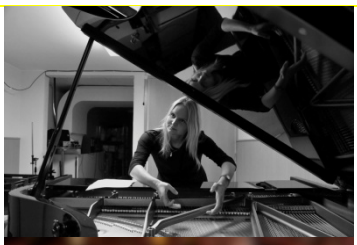

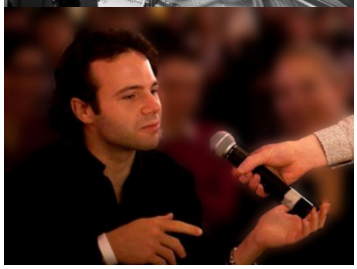

RENEWING CONTEMPORARY MUSIC COMPOSING, PERFORMING, AND LISTENING EXPERIENCE – IMMERSION AS PART OF THE CREATIVE PROCESS AND RECORDING
(Full Paper and Live Performance)

Topic: (Music, Gamification, Audio, Immersive Experiences)

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Abstract
The potential of virtual reality tools and the variety of software suitable for creating interactive music systems and sound environments provides artists, sound engineers, and music listeners more technical and artistic room than ever before. On top of enriching and facilitating the creative process of professional artists, VR technologies can also bring the music and visual contents of an artwork nearer to the audience, allowing them to better immerse themselves in the experience. Moreover, implementing such systems may help to bring more audiences to experimental contemporary music, thus also playing an important role in renewing the classical music culture. Hans-Peter Gasselseder produced the first ever virtual reality ambisonic recordings of two entire operas, "She" (2017 by Maria Kallionpää) and Croak (2018, composed by Maria Kallionpää and Markku Klami). We argue that on top of the artistic value of the musical compositions, a complete virtual reality recording has artistic value on its own right. We will discuss both operas from the composer´s perspective, as well as present their recording processes as case studies from the viewpoint of the sound engineer. As an example of future work, we will also present a new virtual reality recording concept, using Maria Kallionpää´s interactive Disklavier Composition "Climb!" (2016-2017). The work is simultaneously a virtuoso piano composition for a professional pianist and a computer game, that also uses a specifically designed smartphone application for audience members. Although the work contains visual stimuli also in the live performance situation, we argue that the listeners could better enjoy the interactive game element if they could follow the events directly from the performer´s perspective. Our model will focus on bringing the audience members in the middle of the actions of the virtual environment of the computer game.

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Renewing Contemporary Music Composing, Performing, and Listening Experience.

Immersion as Part of the Creative Process and Recording

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Abstract

The potential of virtual reality tools and the variety of software suitable for creating interactive music systems and sound environments provides artists, sound engineers, and music listeners more technical and artistic room than ever before. On top of enriching and facilitating the creative process of professional artists, VR technologies can also bring the music and visual contents of an artwork nearer to the audience, allowing them to better immerse themselves in the experience. Moreover, implementing such systems may help to bring more audiences to experimental contemporary music, thus also playing an important role in renewing the classical music culture. Hans-Peter Gasselseder produced the first ever virtual reality ambisonic recordings of two entire operas, "She" (2017 by Maria Kallionpää) and Croak (2018, composed by Maria Kallionpää and Markku Klami). We argue that on top of the artistic value of the musical compositions, a complete virtual reality recording has artistic value on its own right. We will discuss both operas from the composer´s perspective, as well as present their recording processes as case studies from the viewpoint of the sound engineer. As an example of future work, we will also present a new virtual reality recording concept, using Maria Kallionpää´s interactive Disklavier Composition "Climb!" (2016-2017). The work is simultaneously a virtuoso piano composition for a professional pianist and a computer game, that also uses a specifically designed smartphone application for audience members. Although the work contains visual stimuli also in the live performance situation, we argue that the listeners could better enjoy the interactive game element if they could follow the events directly from the performer´s perspective. Our model will focus on bringing the audience members in the middle of the actions of the virtual environment of the computer game.

1. Introduction

Opera as a music genre possesses a distinct distinguishable character that has prompted a multitude of opinions about its design and structure. Correspondingly, the observed wide range of production styles reflects a multitude of fundamentally different aesthetical ideologies. Whereas traditional opera aesthetics appeal to certain audiences, some others may reject it. Opera, as well as other musical forms with a centuries long history (for example symphony and sonata), require a constant evolution in their design to stay interesting for the audience, as well as for music

creatives. We argue that implementing innovative technologies in contemporary opera performance, composition, production, and recording opens up new aesthetical paradigms that can also reciprocally inform the aforementioned disciplines. This may also lead to reaching a wider audience among demographic groups that would normally not be inclined to the genre. Drawing on insights from legacy recording techniques, the realm of artefacts exhibited by guidance, orientation, and empathic externalization/deixis can inform hybrid approaches for immersive productions. A concerted effort to combine these methods within the context of technologies typically associated with virtual reality (VR) may hold the potential to transport listeners into the middle of the stage action, leading to a genuinely immersive audience experience. Most importantly, by means of the abovementioned interaction between stage production and dialectics arising from the recording artefact, these experiences may be accessible to and favorably affect all audiences alike.

In this paper we focus on two VR opera recording case studies by Hans-Peter Gasselseder: "She" (2017) composed by Maria Kallionpää and "Croak" (2017-2018), composed by Maria Kallionpää and Markku Klami. These are first ever VR recordings made of entire operas that devise 3-dimensional 360-degree high resolution video and 3rd-order Ambisonics sound from multiple perspectives within a bespoke software interface. We argue that, in addition to the artistic value of the operas themselves, the recordings as artefacts per se evolve the experience of a 'stage presence' for the audience in synergy with the stage production to a degree that the newly united form stands as an artwork in its own right.

1.1 Evolving Contemporary Music

Composers throughout the history have been eager to evolve and renew their art form. The pursuit of creating something new and unique exists among contemporary composers perhaps more than ever, which may also be facilitated by the fact that they, unlike their predecessors, have a plenitude of high level technological solutions in their disposal. For example, machine learning, algorithmic composition techniques, gamification, interactive music systems, and different variations of mixed-media solutions can be applied for creating innovative music compositions, and Virtual Reality recording techniques have brought the art of music recording to a whole new level. However, the versatility of available software, faster computers, and other technical options also brings up new challenges with regards to the aesthetics, essence, and identity of musical compositions, composers, performers, and sound artists. This brings us to the question on how to make use of such technologies in a meaningful manner. We argue that technological advancements should never be an end to themselves in an artistic context, but should be used for obtaining such superior results that human artists would not be able to achieve normally. For example, Maria Kallionpää's interactive game composition "Climb", which will be further discussed in this paper, engages an interactive system that generates piano texture that could not be playable by a live pianist: for example, the work contains such overly fast tempi and simultaneous playing on various octave ranges that the physical or instrumental capabilities of a human performer would not allow. Rather than just demonstrating what such a system can do, the purpose for designing the music engine of "Climb" was to contribute to the concept of a virtuoso composition. The tradition of attempting to widen the limits of both the performers and their musical instruments started with the great virtuoso composers such as, for example, Niccolo Paganini, Charles Alkan, and Franz Liszt. We argue that modern, computers, software and other technological tools enable the composers and performers of today to further develop the concept of a virtuoso composition, thus providing more interesting artistic experiences for their audiences.

2.Composing Two Operas: "She" (2017) and "Croak" (2018)

The two operas by Maria Kallionpää, "She" and "Croak" (the latter work in collaboration with Markku Klami), were largely composed simultaneously, and the composition process of the interactive Disklavier composition "Climb" also took place within the same time period, which is why we find that these composing and recording projects should be jointly discussed. The VR recordings of all three works were produced by Hans-Peter Gasselseder. However, as each project was rather different from the others, also the approach with regards to the recording techniques and perspectives was defined according to their individual requirements. For example, whereas the two-dimensional staging of "She" called for the cameras and microphones to be placed further from the happenings onstage, the situation was completely opposite with "Croak", in which they were placed in the middle of the stage, to make the viewers better understand the storyline and the interactions between the different characters of the opera. Whereas the staging of "She" suggested a two-dimensional, fairytale-like environment (Henry Rider Haggard´s novel "She" was selected as the plot of the opera due to its timeless and dramatic time travel adventure story that the composer found to be well adaptable for this kind of a musical drama), "Croak" was set to be a first-person experience, which had to be taken into account when customizing the recording plan.

Although "Croak" and "She" have many points in common (for example, the use of harmonies in both works is relatively similar), they differ from each other in terms of orchestration, storytelling, and staging. Whereas "Croak" engages a traditional middle-sized orchestra, "She" uses an ensemble with singular instruments only, with exception to the strings section, which is of a regular size. Moreover, the composer uses extended instruments in the latter work: the combination of Theremin and Magnetic Resonator Piano underline the divine characteristics of the main protagonist "She"/Ayesha. Rather than just using these instruments because of their exceptional sonic qualities, their function is to serve the drama and structure of the work. Furthermore, whereas composers typically write for Theremin very similarly like they do for voice, in "She" the Theremin part often utilises the extreme instrumental registers. Such orchestration refers to Kallionpää's previous composition "The Song of War (2014) for orchestra, soprano, and Theremin soloists, which was composed for Theremin virtuosa Lydia Kavina. The unusual way of instrumental writing resulted from the tight-knitted composer-performer interaction and collaboration. Similarly to "She", also "The Song of War" contains a superhuman female main character whose presence is emphasized by using this non-traditional instrument.

Conversely, rather than in its instrumentation, the originality of "Croak" mainly lies in its staging: the work is the very first puppet theatre opera produced in the Nordic Countries. From the composer´s perspective the main challenge was taking into account the constant presence of the human-sized puppets that were specifically manufactured for the needs of this project by Viktor Antonov. How to consider the timing and the movements of the puppets, as well as the noises that they might cause? Both the stage design and the looks of the puppets were developing simultaneously to the composition process of the music. Although the original setup plan was aesthetically rather traditional, Antonov and the stage director Anna Ivanova-Brashinskaya decided to modernize it to better match to the musical material that they found to be stylistically more experimental than they had expected. Because of this, Antonov changed the design of the puppets: the new ones were made of lighter materials than the originals, and also the stage design became more minimalistic. Because many visual effects (such as, for example, Croak swimming under the water) were made by using a large and flexibly moving canvas of thin plastic, its rustling also put its mark on the sonic world of the work, as well as on the VR recording that will be discussed below.

3. "Climb!": An Interactive Game Composition for Disklavier

The concept of a "game composition" was originally presented by Kallionpää and Gasselseder in 2016 [1]. "Climb!" was the corner stone of Kallionpää´s artistic postdoctoral research project "Automatizing Musical Expression in Real-Time Performance Settings: Procedural Music Systems as a Composition Technique" that was hosted by the Aalborg University and the Mixed Reality Laboratory of the Nottingham University. The work is a result of the long-term collaboration between the researchers of the Mixed Reality Lab and Kallionpää: on top of artistic practice itself, this interdisciplinary project involved research in the fields of computer sciences, engineering, and visual arts.

"Climb!!" is a non-linear musical composition that combines the ideas of a classical virtuoso piece and an interactive computer game. The performer plays with and against the machine in a virtual game environment, meaning that the pianist performs together with a Disklavier that is controlled by an interactive system. "Climb!" is a super instrument work that intends to multiply the capabilities of both the instrument and the performer. With the combination of the pianist, Disklavier, and live-system, such effects that would not normally be reachable can be achieved. These include, for example, playing the piano in multiple octave ranges simultaneously, choosing fast tempi that would be otherwise impossible to play, and using complex rhythms that only a computer would be able to perform. The pianist and the computer form a seamless unity that enables virtuosity that exceeds the physical and cognitive limits of a human performer.

Computers can have a profound impact on music composition and performance, the works of Iannis Xenakis (1922-2001), Karlheinz Stockhausen (1928-2007), Pierre Boulez (1925- 2016), and their many other contemporaries being illustrative examples of this [2]. "Climb!" is its composer´s most technologically inspired work, as it engages an interactive digital score, Yamaha Disklavier, interactive visuals, a smartphone application (on which the audience members can follow the progress of the game/musical performance), and an online archive that saves all the performances. The composer regards the online archive to be an artwork itself, a collage: so far it consists of various concert performances by three pianists (Anna Veinberg, and Zubin Kanga, and Maria Kallionpää). The interactive system of "Climb!" is based on the Muzicodes software that was developed by the Mixed Reality Laboratory. By embedding codes (musical motifs or fragments that the system recognizes and uses for triggering its programmed functions) in the digital score, the composer created a nonlinear entity in which the pianist or avatar navigates. The structure of the entire composition depends on how the performer plays the codes. Depending on whether the program recognizes the codes or not, one lands at the different point in the score. There are two kinds of codes, namely the simpler ones that just to trigger effects (for example, inform the system when the Disklavier should play) and the "challenge codes" that are more complex and that have a structural meaning. The latter function similarly like leitmotifs, as they are musical "keys" that define the course of the performance. Moreover, various functions of the system are randomized. For example, different kind of filters (for example reverberation or alteration of the sonic spectrum) are applied onto the musical performance in an arbitrary order. These symbolize the weather conditions that are part of the narrative of the game.

3.1 The Form and Narrative of the Composition

As discussed above, "Climb!" got its inspiration from the modern computer games. The game narrative is based on a story of an avatar climbing on top of a mountain. On their way to the summit, they face challenges, animals, landscapes, wanderers, hallucinations, and various other situations. The story is communicated to the audience with pre-composed contemporary classical music miniature pieces that together form a large-scale virtuoso composition with a duration of

between 25 and 30 minutes, supported by the interactive visuals and the smartphone application. A relatively abstract picture of a mountain is reflected on a canvas in a concert space. The mountain changes its colour and shape in accordance to the music, and the smartphone application shows in which part of the mountain the avatar is located, the route they used, the approaching challenges, as well as the names of the movements that the pianist is currently playing. Moreover, the routes taken in previous concert performances can also be viewed on the application.

"Climb!" consists of three "macro compositions" that symbolize the three paths to the summit. The pianist or gamer chooses one of them by playing one of the three default codes at the end of the very first movement ("Basecamp"). The abovementioned challenges and encounters are interpreted into music by creating "micro compositions" ("events") that occur in the course of the three main paths. Within every performance the paths and events get organized differently, as they branch to each other depending on how the pianist interprets the musical codes. Moreover, the randomized sound processing ("the weather conditions") also affects the sonic colour and the sense of acoustics, to which the performer has to adapt their interpretation.

4. The Immersive Opera: Producing a VR Experience

In addition to their artistic considerations, the operas "She" and "Croak" featured some strong technical aspirations that set them apart from previous offerings in the genre. To the best of the authors' knowledge, both productions represent the first full-length recordings of an opera in an immersive format that supports 3-dimensional 360-degree video and audio for playback and control in virtual reality (VR; i.e. head movements as well as six degrees of freedom facilitated by volumetric simulations in "CROAK VR"). Apart from an implementation for VR, a further desideratum of the recording plan was to maintain high compatibility with legacy as much as next generation formats, with supported playback setups ranging from traditional channel-based systems (such as 5.1 surround sound) to full 360-degree object-based surround (either rendered binaurally or on an arbitrary number of loudspeaker pairs). Whereas both operas share a common paradigm in their recording philosophy, that is to offer the spectator a perspective otherwise unattainable to an audience member of the live show, they also showcase differences in the application of immersive recording techniques due to circumstantial requirements set by the stage design/directing, musical material/orchestral layout as well as legal considerations.

With regards to the video material, for "She", a two-dimensional 360-degree format was to account for the entirety of stage properties being simulated by projections on a translucent screen positioned anterior to the characters on stage. This positioning allowed spectators in VR to move around in the scene, looking at the stage in the front and at the orchestra at the back Due to the play directors' intentional use of a stage design that was to mimic a two-dimensional perspective in reference to the mythological character of the narrative, it was decided to uphold this quality while extending its immersive potential by placing the main camera rig (Insta360 Pro in 2D at 8k resolution, see [6]) closer towards the characters on stage (approx. 2 meters to camera objects) as compared to standard setups in VR production (approx. 4-6 meters if shot close-up). This allows users to experience the characters from up close but also to zoom out of the equirectangular source (an option provided in the user interface of the bundled software) as to get a view of the overall 'canvas' that the stage design was intended to convey. For audio, the same rationale came to effect by placing a prototype 3rd-order Ambisonics microphone (Zylia ZM-1d; prototype kindly provided by the manufacturer Zylia [5]) in front of the orchestra (i.e. at the level of the conductor). This acoustic perspective was chosen to underline the staging (i.e. everything placed in front of the spectator), but also to add the sense of place (i.e.

offering a more holistic acoustic representation of the situational context with less direct and more reverberant sound reaching the microphone) by positioning the microphone further back from the camera rather than placing both at the same position (, which would represent the standard dictum in VR productions, see [4]). In addition, the flexibility achieved by recording in Ambisonics allowed to focus on different sound sources during post-production as much as during real-time playback in the final product. To give an example of a typical use case, turning ones' head towards the magnetic resonator piano at the left side of the orchestra pit will turn its sound more prominent in comparison to the otherwise dominant orchestral texture within the mix.

When reflecting on an early review of the methodological insights gained while recording "She", for the visual domain, on the one hand, the added sense of 'being there' was achieved by moving closer and thus offering more detail on the character interactions. For audio, on the other hand, the counter-approach seemed most effective by moving further away from the scene and subsequently adding a holistic sense of space and situational context to the experience (see [3] for some theoretical considerations related to this finding).

In contrast, the production of "Croak" exhibited a rather different set of criteria to be respected by the recording. Whereas the staging of "She" necessitated a two-dimensional approach with added depth (for the sake of supporting the sense of involvement as much as 'being there'), the production of "Croak" posed a challenge in the opposite direction. The production made little use of stage properties but rather had its characters move a lot and explore the depth of the stage to large extend. Moreover, the nature of the main characters being represented by life-size puppets controlled by puppeteers would have made spectators prone to confuse character relationships if the same two-dimensional recording setup had been used as in "She". Thus, rather than positioning the recording gear close-up (visual) / far-off (audio), the recording rationale opted for a wide and more distant view of the stage that embraced depth by means of a three-dimensional video (as compared to the two-dimensional approach applied in "She") and a more surrounding audio experience. This allows spectators to differentiate the suggested layers of diegesis that are inherent in puppet theater where the representative characters ("puppets") are accompanied by puppeteers, and in the special case of opera, also by individual singers. Where "She" required depth in its depiction of the stage, "Croak" necessitated a sense of segmentation of the different hierarchical diegetic layers suggested by the positioning of individual actors/singers. With puppets commonly positioned in the mid-front, singers at the side edge of the stage, and puppeteers further behind the former two, a three-dimensional video in 360-degrees enables spectators to differentiate these (hierarchical) layers. Another complexity specific to "Croak" posed the stage lighting, which varied in color and, in combination with the shadows cast by the puppets, caused interesting reflections onto the sides and rear of the concert hall. These reflections were mainly visible from the audience's perspective. In order to capture the depth of the stage as well as an alternative perspective of the hall from the audience's view, the main camera rig (Insta360 Pro in 3D at 6k resolution, see [6]) was placed approximately 6 meters at the edge between stage and orchestra pit. Furthermore, the primary rig was extended by a secondary 360-degree camera setup (2x Kodak SP360 4k, see [7]) positioned between the first row of the audience seating area as well as above the conductor in the orchestra pit. For the final VR experience, this configuration enables a change of perspectives during playback when zooming out from the footage recorded on the primary camera and blending over to the material that was shot on the secondary camera rig. Due to the lack of available software allowing for the playback and control of different camera perspectives in VR, we developed a custom player accounting for the aforementioned requirements within the game development platform Unity 5. Opting for a 2.5D paradigm that involves the mapping of flat surfaces onto 3D-objects, the player software devises cube projections and static displacement maps to place the camera footage within a 3D-environment. The footage obtained from either camera perspective can be assigned to individual hotspots. These come to effect upon reaching a threshold value of the zoom control parameter and allow for seamless transitions and blending of both camera perspectives.

In this way, if the user decides to switch perspective or focus on another object shown on stage or in the audience room she/he is always presented with the highest resolution of the chosen perspective.

Moreover, as different perspectives are being blended between two pseudo-rooms of the same scene (i.e. stage and audience room), a careful consideration of camera positioning holds the promise to generate transitionary scenes within the virtual environment (i.e. extrapolating new virtual perspectives, not shot with physical camera positions, but generated from footage obtained from available physical perspectives) and approach a six-degrees-of-freedom (6DoF) volumetric simulation paradigm where users could move around freely within the captured video footage as part of the tracking along the translation axes within a virtual environment rather than to be limited to rotational orientation alone. To explore this idea, an in-development version of "CROAK VR" uses a mixture of photogrammetry of a static scene while blending in extra layers that exclusively contain the moving parts of the scene (i.e. puppets and puppeteers). As only the primary camera position was recorded in stereoscopic 3D, the required depth information (i.e. depth map using shades of black/white to represent distances from the camera) was projected from the primary onto the secondary camera rig. However, this procedure involves a lengthy process of rotoscoping and shading moving objects onto the corresponding depth map of a scene. By the same token, the extrapolation of virtual perspectives may suffer of artefacts related to the lack of resolution and spatial synchronization between depth maps obtained from the different camera models and positions. Moreover, due to the nature of the flat capturing inherent to video, we are missing out on information that lies behind those objects facing the camera (i.e. accuracy of textures is two-dimensional but displaced within a three-dimensional volumetric simulation). Whereas this working method would pose the risk of artefacts separating acting characters from the remainder of the scene (as in the lack of accounting for shadows and blending silhouettes), the specific staging situation of Croak allowed to make such sacrifices at the benefit of the overall experience. In this connection, it was found that in comparison to the unprocessed footage, the artefacts resulting from unsynchronized depth processing contributed to an appearance of puppet characters that was more abstract and divorced from reality, whereas the remaining acting parties (puppeteers, singers, orchestra/conductor, audience) were almost left untouched by the alterations. It is believed that this technique supports the user in distinguishing the different layers of the diegesis, which suggests three acting parties (puppet, puppeteer, singer) as an agent of a single character and thus has to tackle the issue of assigning agency of various expressions (appearance, action, singing) to a single originator.

As for audio, the staging as well as setting of "Croak" implied moving closer with the Ambisonics microphone (Zylia ZM-1d prototype) towards the stage action. Therefore, the microphone was placed between the stage and the orchestra (rather than in front of the orchestra as in "She") and also functioned as the center of a Decca tree setup that was supported by an additional 12 spot microphones. The reasoning for a closer acoustic perspective for "Croak" was two-fold. First, the lack of a contractual agreement between the producers and the orchestra meant that no orchestral material could be released on a public recording. Thus, a solution had to be found that would allow separating the voices of the singers and choir on stage from the orchestra, which would later be replaced by realistic virtual orchestrations. For that purpose, a drier (i.e. less reverberant) signal was preferred from which voices could be isolated during post-production. This was made possible by a bespoke procedure that focuses individual sound sources in a first step (with the help of directional focusing achieved by Ambisonics recording techniques; as realized in software such as Zylia Studio Pro, see [9]) and separate these from the remaining interfering signals during a second step of post-production (i.e. using spectral editing as well as specialized software such as Audionamix ADX Trax Pro 3, see [8]). Subsequently, a multitude of isolated signals derived from the virtual microphones of the Ambisonics signal is used to phase-cancel harmonic noise and sum the target sound source (i.e. the voice of a soprano during a loud orchestra tutti). Being able to isolate individual voices and instruments from a single physical microphone position allows for elaborate post-production

techniques that facilitate mixing in object-based audio formats and thus enhance quality and flexible adaptation of immersive audio content for different output formats. The second rationale for a closer acoustic perspective goes in line with the previously outlined reasoning behind the camera setup. The recording intended to capture the singers more up-close as to enable spectators to locate the source of a voice and identify characters at a higher accuracy, thus facilitating diegetic orientation. As a result, the audio tracks of the VR presentation place spectators in the middle of the action, with the singers and choir positioned at the front and the orchestra at the back of a 360-degree sphere.

Conversely to the findings on "She", the sense of spatial awareness within the audio recording of "Croak" was less invested into the room/environmental aspects of the concert situation rather than the dramaturgic nature of character relationships and its construction of absorption (see [3]). In contrast, the video material served as a means of enhancing the sense of space and context, a function that in "She" was predominantly covered by the audio recording. Following this, the varying conditions of two opera productions led to two quite different recording approaches of immersive content for VR, a format that in other genres holds the common notion of standardized camera and microphone configurations. However, these two examples demonstrate the need to consider the individual requirements of the specific content as well as its associated genre. Whereas an opera recording in a legacy format (i.e. two-dimensional 16:9 aspect ratio) leaves it to the film director to edit camera cuts and foci of the action, VR hands over such responsibility to the spectator/user. It is thus even more important to suggest the user with specific contextual functions respective to the visual and acoustic domain of the presentation to establish guiding markers of the diegesis between the meta-virtual (i.e. the depiction of the stage performance) and its (infra-) virtual realm informed by the nature of the physical environment (i.e. the concert hall). If made aware of these roles on an implicit level during initial contact with the content (i.e. the overture of "Croak"), users are more likely to recognize the meaning structures as well as the extend of possible actions on different layers of abstraction (i.e. what's to be depicted on stage versus what physical setting it is being staged in). Giving users of VR an initial understanding of the relevance and modal representation of each of these realms builds an authentic representation of a truly immersive experience that is more than a documentation of its original performance.

5. The Immersive Concert: Recording for Volumetric Simulations

The third offering of our VR lineup tried to account for the shortcomings and improve the efficiency of the production pipeline in use during the previous two recordings. Furthermore, it considered the time limitations of the setup inherent to the location (Abbey Road Studios, London; Studio 2) and occasion of the concert (FAST research network at an open event as part of Abbey Road RED). In contrast to "She" and "Croak", the performance "Climb!" does not belong to a representative dramaturgic genre per se, but rather showcases an affinity towards programme music. Despite its focus on a narrative as part of the conceptual and compositional structure, the audience finds itself as part of a concert setting that deviates from the normal by means of an interaction between the player and the piano. Because "Climb!" does not rely on a uni-directional performance paradigm but affords a constant change of focus between two agents, the recording plan had to account for two protagonists rather than one; that is the pianist and the motorized piano itself. If not presented with the auto-performing piano en face, the audience would have difficulty in entrusting the performance as being authentic. This is true especially in the light of the electro-acoustic setup that was used to simulate the weather conditions (i.e. filter effects applied onto the audio stream obtained from microphones positioned inside the piano). Naturally, under those conditions the audience would be presented with sound originating from the acoustic instrument as much as with the processed signal output by speakers. Thus, it was important to support the users'/audiences' awareness of the two interacting agents, where the first would impersonate the human nature of the climber while the other laid out the circumstances and challenges of the environment where artificial, superhuman powers (i.e. weather or

natural adversaries/challenges) outreach human limitations (note: ironically, it appears to be the most efficient path to mimic nature in music by opting for a rendering of artificial otherness that lies beyond the human grasp). Hence, the user would have to witness the action on the piano keyboard itself to understand the struggle between these two intersecting worlds. In order to account for these requirements, a first-person perspective was chosen where the main camera (Insta360 Pro in 3D at 6K resolution) was positioned right above the pianists' head. This perspective places the action of piano keys and hands of the pianist as well as the overall happenings inside the studio (i.e. technicians, audience) at the center of attention while the head of the pianist would be positioned in the periphery of vision at about 150-degrees vertical.

Ultimately aiming to allow the user to walk around the piano in 180 degrees towards the right of the VR environment we set out to put in practice a more efficient method to capture the information required for the methods tested as part of the alpha "CROAK VR" experience. In total, four stereoscopic camera rigs were positioned in a half circle around the piano. Apart from the aforementioned first-person perspective, the second camera rig was placed towards the right of the performer at 45 degrees (2x Kandao QooCam in 3D at a combined 8K resolution; custom mount), the third rig at 90 degrees (2x Kandao QooCam in 3D at 8K) and the fourth rig at 180 degrees (2x Kodak SP360-4K in a stereoscopic configuration). In addition, a further camera (Insta360 Pro in 3D at 6K resolution) was positioned within the ranks of the audience's seating area.

Similar to "CROAK VR", the in-development "CLIMB! VR" experience will enable users to switch and seamlessly blend between these camera positions. However, the exclusive use of stereoscopic cameras facilitates the process of deriving depth information for the application with displacement maps (for a detailed overview see Gladstone, 2018a; and the Stereo2Depth python script, Gladstone, 2018b). A bespoke procedure of spatial synchronization (i.e. pixel-by-pixel mapping of depth maps between camera positions) of the footage allows us to benefit from the relatively high number of stereoscopic 360 cameras surrounding the piano. Hence, it is possible to combine these perspectives and blend between depth maps and their associated displacement vertexes from each position at a relatively low count of artefacts. The blending between positions occurs at a relatively low threshold when the user moves outside the hotspot area of an active camera position to the degree that 6DoF related artefacts along the horizontal plane outweigh artefacts from a neighboring camera position. By making use of these methods, "CLIMB! VR" will allow its users to roam around the piano and experience different close-up perspectives of the performance, as in following the key action right above the shoulders of the performer or stepping over to observe the piano hammers and strings or to look at the pianist and audience from behind the grand piano. More importantly, 6DoF and volumetric simulations enable users to explore what lies in-between these camera positions and disclose a more immersive experience than what was originally bargained for with traditional stereoscopic recording equipment.

6. Conclusion

Opera is an intriguing space to work when one wants to explore the design and development of new technologies that might impact up the composition, performance and staging of such work. Working in such spaces are complex, but there is value in understanding the way that this art form can offer exciting and new possibilities to further understand the way that new technologies relating to autonomous systems for compositional practice, Virtual Reality spaces for performing and non-linear narrative/performance structures can be developed and applied in the real world. However, technological development should never be an end to itself, but to function as a vital part of the artistic methodologies used in a classical music composition. If used this way, the evolution of technological tools can significantly enrich the creative outcome and allow the listeners, as well as the performers and composers, to experience an opera performance in an immersive and artistically meaningful manner.

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