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An Immersive Musical Exploration of Nature in Virtual Reality Environment

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Abstract. Rapid ecological, cultural and social changes pose huge problems for humanity since they represent a great danger to the future of the planet Earth. These current transformations encourage art-science research which has proven to be a valuable means for communication of such challenges. Creative media artists effectively address and critically discuss the impact of cultural and social changes on environment. In the field of virtual heritage, they combine virtual reality and cultural and natural heritage offering an opportunity for the audience to become an integral part of the immersive heritage experiences. This conceptual article offers theoretical reflections on the role of hybrid audiovisual media, as a fusion of virtual reality, music and soundscape, in communicating the importance of natural heritage protection. Conceptual framework of this research combines concepts from new media theory and theory of musical emotions including BRECVEMA framework. Following new media theory, with aim to communicate meaning, this project includes creation of the Virtual Heritage Exhibition, representing natural heritage of Hong Kong, and in particular Hong Kong UNESCO Global Geopark and Indo-Pacific Humpback Dolphin. Musical content and semiotics are in the form of sonification, while visual semiotics are audio-reactive visual effects applied to the natural landmarks in the virtual reality 360 videos. To evaluate if the goal of creating audio-visual virtual heritage environment that allows intercultural communication and learning for the audience is achieved, user experience evaluation is based on the concepts of and theory of musical emotions including BRECVEMA framework.

Keywords: Nature heritage; creative media; hybrid media; virtual heritage exhibition; BRECVEMA framework.

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1. Introduction

Human beings have existed for only a brief period relative to Earth's geological history, yet the scale and impact of human activities have become the primary drivers of contemporary environmental changes (IPCC, 2021; Brondizio *et al.*, 2019). Rapid climate change is evident, with global temperatures rising by over 1.2°C compared to preindustrial levels due to anthropogenic factors (WMO, 2021). The rate of mass loss from the Greenland and Antarctic ice sheets is increasing, leading to accelerated sea-level rise (Voosen, 2020). Current extinction rates are estimated to be approximately 100–1000 times higher than natural background levels (Pimm *et al.*, 2014). An estimated one million species will be at risk of extinction unless significant measures are taken to mitigate the major drivers of biodiversity

loss, such as climate change, urbanization, and deforestation (Brondizio *et al.*, 2019). Failure to address these issues could lead to a continued escalation in extinction rates, potentially culminating in a sixth mass extinction event (Barnosky *et al.*, 2011).

To promote the sustainability, new media artists address and critically discuss the current environmental transformations, including the climate change, through the use of hybrid practices of art, science and technology (Grassini & Ratcliffe, 2023). Applying new media technologies, they creatively transform natural and cultural data into different forms of new media arts, such as interactive virtual reality (VR) art, sound art, simulation video games, and cinema, to help engagement with wider audiences. In the field of virtual heritage (VH), incorporating VR and cultural heritage (CH), they provide cultural and natural evidence using VR imaging technologies (Champion, 2021). This area is rapidly evolving with digital technologies implementation and maturation of processes in the research and functional methodologies. It offers an opportunity for the audience to become an integral part of the realistic immersive digital CH experience, including natural heritage and intangible cultural heritage (Privitera, Fontana & Geronazzo, 2024). Since the climate change has severe impacts on cultural heritage, VR, as an excellent technological tool for communicating and experiencing the effects of ecological, social and cultural changes, is widely used in museums, companies and foundations, providing realistic CH preservation experiences (Reaver, 2019).

Due to the potential of sound and music to articulate the global ecological, cultural and social crisis, creative connections between music and sustainability have been established (Kagan & Kirchberg, 2016). In this sense, sonification is one of the art-science approaches that allows documenting and communicating the large-scale transformation of the nature by conveying information and perceptualizing data. This is due to its potential to convert scientific data, such as air and water pollution, climate change, earthquake, and ocean data, from natural and urban environments, into music. The ability of music to draw on deep and illicit levels of both verbal and non-verbal images, symbols, feelings and systems of social awareness makes it a vital element of realistic immersion in the VR. As the renovation of our bio-culture is essential for the survival of our planet, in order to increase public literacy and social engagement with ecological issues through encouraging the intuitive, creative thinking and engagement (Scheffer *et al.*, 2015), VR creators should always include music and immersive audio as an essential component of their VR and CH applications.

Although the fusion of VR, music and spatial sound has a great potential, the underlying multimodal psychological processes and systems are still not fully understood. Furthermore, a significant challenge in conveying climate science to the public is addressing the gap between understanding and taking action (Moser & Dilling, 2011). This gap highlights the insufficient shift in environmental behaviours by individuals or society despite increased communication about ecological crisis and greater public awareness. To close this gap, effective communication strategies should address cognitive, emotional, and behavioural aspects (Nelson *et al.*, 2018). For instance, individuals should first comprehend the problem, then have emotional and cognitive reactions, and finally, translate these responses into active behaviour change. Studies have demonstrated that both the content of the message and the degree of VR immersion (Shin, 2018) can affect the strength of emotional responses and subsequently influence behaviour (Baberini *et al.*, 2015). Music and sound within VR environments have gained attention for their potential to enhance

immersion and the sense of presence, which is thought to affect emotions and strengthen individuals' connection to the content (Privitera, Fontana & Geronazzo, 2024).

The central question in this research is: what are the capacities of music and sound communication within VR environment for evoking emotional responses, and thus, potentially promoting effective environmental communication? To answer this question, the theoretical frameworks of this research combine concepts from the new media theory and theory of musical emotions, including BRECVEMA framework. This framework aims to emphasize the potential of music in conveying messages about environmental protection through the creation of realistic VH experiences for the audience.

2. Method

As a conceptual paper of a scientific experiment, this paper applies literature studies, exploring relevant literatures and theoretical frameworks that help to answer the main question of this study. In this study, I identified some useful theoretical tools, such as new media theories, virtual heritage, BRECVEMA framework, and creative-semiotic works. These theoretical sources are applied to an experiment of musical exploration of natural and cultural heritage of Hong Kong. Creative outcome of this experiment is an Interactive Virtual Heritage Exhibition titled 'Immersive Journey Around Hong Kong'.

In order to evaluate the goal of creating realistic musical experiences that allow immersive musical exploration of cultural heritage in a virtual reality, user experience evaluation is applied based on the theory of musical emotions, including BRECVEMA framework. This framework takes an evolutionary perspective based on the great capacity of the sound perception to activate emotion induction mechanisms, conceptualized as information processing systems operating at various brain levels. These various emotional mechanisms managed by different 'brain networks', have evolved progressively in a particular order, ranging from basic reflexes to more complex judgments. Each mechanism uniquely responds to specific configurations of information within the music, the listener, and the context, collectively termed the 'musical event' (Juslin, Barradas & Eerola, 2015).

3. New media theories

Although the exploration of new media has long been integrated into communication studies, the formal development of new media theory emerged only in the 1990s (Littlejohn & Foss, 2009). The rapid expansion of digital media from the telecommunications and information technology sectors during this time led media and communication studies to evolve and tackle new research topics. This transition has required not only the examination of new media forms, but also the investigation of how traditional media are being re-mediated. The establishment of new media studies as a distinct area within communication theory is also supported by the argument that traditional media environments have been fundamentally transformed, not just by technological innovations, but through significant, qualitative shifts at the ecological level (Holmes, 2012).

One of the earliest assertions about the profound impact of media was made by Marshall McLuhan (1964), who contended that the electronic revolution of the 1950s had such a profound effect that it rendered educators as displaced persons, living in a world vastly different from the one in which they were raised. He argued that this revolution

created classrooms without walls, as telecommunications and television introduced new and simultaneous information, leading to electronic society.

McLuhan's (1964) theories from the 1950s proved to be prescient for the Internet Utopians in the 1990s, who declared that the advent of the Internet marked the fulfillment of McLuhan's vision through the provision of instantaneous information. However, despite efforts to incorporate McLuhan into Internet studies, his work does not directly address the specific revolution in electronic media identified by contemporary new media theorists. This revolution pertains to the transition from broadcast to networked electronic media forms (Holmes, 2012). This shift represents an internal transformation within electronic media itself.

While McLuhan's (1964) insights into media globalization (the global village) and convergence (the interaction between media forms) laid some foundational concepts for new media research, the media revolution that currently drives new media theory is rooted in the exploration of a second era of electronic media characterized by interactivity. The excitement surrounding the Internet-led new media age reached its peak in the mid-1990s. Some seminal works, such as journalistic utopian visions of George Gilder, Nicholas Negroponte, and Howard Rheingold and theoretical explorations of Mark Poster and Sherry Turkle, have heralded the end of traditional broadcast media and the emergence of interactive networks (Holmes, 2012). In Life After Television, Gilder (1994) proclaimed the demise of television's master-slave model, replaced by networked media where everyone has the potential to become a broadcaster. In contrast to television, where the capacity to shape, store, and manipulate images was restricted to broadcasters due to economic and technical limitations, the technology of the time could not be included in individual television sets (Holmes, 2012). However, advancements such as the transistor (1948), the microchip (1958), and the fiber-optic cable (late 1970s) rendered analogue television technology obsolete.

Proponents of the second media age contended that audiences would no longer accept the passive role imposed by television once active participation in a networked, decentralized medium became feasible. In the Second Media Age, Mark Poster (1995) argued that the Internet would offer an alternative to the restrictive broadcast model, facilitating a system with multiple producers, distributors, and consumers. This post-broadcast era would not only end the traditional concept of the audience but also introduce a personalized experience, where individual preferences and interactions with content, such as through interactive television or web page bookmarking, would replace the mass culture of broadcast media. By the late 1990s, the notion of the second media age had solidified into a foundational element of new media theory, influencing the evolution of Internet studies and cyber studies. New media theory increasingly focused on the ontology of digital media, which was seen as the defining factor that would eventually replace the historical framework of the second media age (Holmes, 2012).

4. Virtual heritage and immersive storytelling

Virtual heritage (VH) utilizes advanced computer-based interactive technologies within VR to visually recreate monuments, artifacts, and cultural aspects, disseminating these representations globally (Cecotti, 2022). This innovative approach has significant implications for education, enhancing learning by providing immersive experiences that deepen understanding of historical and cultural contexts. VH not only broadens access to cultural resources, but also transforms educational practices by enabling interactive

engagement and experiential learning. By leveraging VR, educators can effectively integrate dynamic audiovisual experiences into curricula, fostering enriched learning experiences that transcend traditional classroom boundaries.

The representation of CH in VR expands beyond physical constraints in several ways. Firstly, it enables users to explore remote and otherwise inaccessible locations, overcoming geographical limitations (Soto-Martin, Fuentes-Porto & Martin-Gutierrez, 2020). Secondly, VR allows users to experience historical settings by digitally reconstructing buildings from different time periods, offering a glimpse into their past forms. Cecotti (2022) advocates for the advancement of fully immersive VR environments based on ecological principles, emphasizing their ability to allow users to explore locations without the carbon footprint associated with travel. Physical visits to these sites can lead to environmental degradation exacerbated by issues, including overcrowding and logistical challenges, such as long queues at popular attractions. Through digital preservation and fully immersive VR, future generations can access and experience endangered cultural and natural heritage that may otherwise be lost or damaged due to environmental factors.

Throughout human history, storytelling have been fundamental in preserving CH, serving various purposes from entertainment to the transmission of culture and knowledge (Bassano *et al.*, 2019). As communication methods have advanced over time, storytelling has evolved beyond oral tradition to include mediums such as music, painting, film and photography. The introduction of electronic and subsequently digital technologies has further transformed the dissemination of stories, offering innovative platforms for their preservation and distribution (Privitera, Fontana & Geronazzo, 2024). The heightened engagement and emotional resonance achieved through immersive storytelling contribute significantly to increased interest and comprehension of cultural and natural topics, thereby enhancing knowledge dissemination.

In the realm of cultural and natural heritage storytelling, exploration of audio rendering and mixed reality began as early as the 1970s (Privitera, Fontana & Geronazzo, 2024). In recent years, technology has become indispensable in the realm of digital humanities, significantly impacting the dissemination, education, and research of natural and cultural heritage storytelling. VR applications have proven beneficial in numerous presentations of cultural and natural sites (Cecotti, 2022).

A pivotal aspect in enhancing cultural and natural heritage experience is the concept of a three-dimensional soundscape, which refers to the acoustic environment as perceived and experienced by individuals within a specific context (Lee, 2016). Soundscape contributions are particularly valuable in tourism and cultural heritage, enriching visitor experiences. Immersive storytelling within VR further leverages these technologies to deepen engagement and presence. This approach utilizes VR techniques to craft narratives that immerse users deeply, fostering emotional connections and facilitating interactive learning experiences (Bekele *et al.*, 2018). Integral to the immersive experience is the role of audio, which plays a crucial part in enhancing user immersion and providing contextual information about the virtual environment (Monache, Misdariis & Özcan, 2022). As such, audio elements in VR not only contribute to the sensory richness of the experience, but also serve as a vital medium for conveying information and enhancing the overall immersive storytelling process in cultural heritage contexts.

5. BRECVEMA framework: from sound to significance

The impact of sound on listeners can be remarkably profound. It is posited that auditory stimuli may be more 'intimate' compared to visual stimuli, as sound is perceived as being more deeply internalized within our consciousness (Thompson, 2009). The influence of sound is particularly evident in the context of music. According to Juslin *et al.* (2008), music is a daily experience for many individuals in the Western world. During a substantial number of these encounters, the music arouses emotional responses, which can be quite profound.

However, the capacity of music, composed merely of abstract tonal sequences, to evoke intense emotions is frequently regarded as one of life's great mysteries (Juslin, Barradas & Eerola, 2015). Furthermore, listeners exhibit considerable variation in their emotional responses to music (Sloboda, 1996). Therefore, Gutheil (1952: 11) questions if it is possible music and emotion research to "ever reach the goal of science, namely to discover laws of cause and effect in order to predict the results". A key aim of scientific research into music and emotion should be to clarify the mechanisms by which musical sounds acquire and convey emotional significance (Juslin, Barradas & Eerola, 2015).

While limited empirical research has tested theories regarding the mechanisms underlying emotional responses to music, various scholars have proposed potential mechanisms over the years, often focusing on one or a few specific aspects (Juslin & Västfjäll, 2008). Meyer (1956) is often recognized as the pioneering modern scholar who highlighted the significance of psychological theory in exploring the connections between musical structure and emotional response. He proposed a valuable theory of 'musical expectancy' to address this relationship. Dowling and Harwood (1986) stated that 'conditioned responses' are tools composers use to elicit emotions, providing various examples to illustrate this principle. Baumgartner (1992) suggested that 'episodic memory' significantly influences emotional reactions to music, supporting this assertion with survey data. Waterman (1996) made an early effort to apply 'appraisal theory', as defined by Ortony, Clore, and Collins (1988), to musical events. Juslin (2000) argued that 'emotional contagion' through voice-like features in music accounts for some musical emotions. Although Sloboda and Juslin (2001) and Scherer and Zentner (2001) explored these mechanisms, they did not develop an integrated framework with hypotheses to guide future research. The most thorough attempt to describe such mechanisms began in the mid-2000s, leading to the development of the BRECVEMA framework (Juslin, 2013; Juslin & Västfjäll, 2008; Juslin *et al.*, 2010).

Patel (2008) highlights that humans possess a unique capability to interpret sound. An ecological view of sound perception posits that the survival of our early ancestors relied on their ability to recognize patterns in sounds, extract meaning from them, and modify their behavior accordingly. This perspective underpins the BRECVEMA framework proposed by Juslin and Västfjäll (2008), which seeks to explain emotional responses to music through a comprehensive set of psychological mechanisms.

The BRECVEMA framework takes an evolutionary perspective based on the great capacity of the sound perception to activate emotion induction mechanisms, which are conceptualized as information processing systems operating at various brain levels. Based on this assumption, it is theorized that these various emotional mechanisms, managed by different 'brain networks', have evolved progressively in a particular order, ranging from basic reflexes to more complex judgments. Each mechanism uniquely responds to specific configurations of information within the music, the listener, and the context, collectively termed the 'musical event' (Juslin, Barradas & Eerola, 2015).

Furthermore, since BRECVEMA framework emphasizes the great significance of sound perception for emotion activation (Juslin, 2011), it can be utilized to understand psychological aspects within immersive experiences, including the interaction between immersive technologies and our perceptual, cognitive, and emotional states. More precisely, this framework can be utilized to understand how sound and music can evoke emotions within immersive environments. Moreover, the BRECVEMA framework posits that all mechanisms and aesthetic judgments share a commonality in their reliance on psychophysical interactions between 'external' features of the environment (such as music and context) and 'internal' characteristics of the perceiver. While a particular piece of music may convey specific types of information, the activation of these mechanisms is also contingent upon the listener's attributes and the surrounding context (Juslin, 2013). In the realm of immersive experiences, the BRECVEMA framework offers a thorough understanding of how sound and music can evoke emotions within virtual environments. Accordingly, it is crucial to account for both the audience and the context when designing virtual experiences, as this consideration enhances the potential to affect the emotional domain and creates musical events that significantly contribute to psychological immersion.

BRECVEMA framework includes eight mechanisms:

a. Brain stem reflexes represent an automatic attentional response to basic acoustic features, such as intense or rising changes in loudness or tempo. Brain stem reflexes related to music are rooted in the initial stages of auditory processing.
b. Rhythmic entrainment is a gradual alignment of an internal body rhythm, such as heart rate, to an external rhythm in the music (Harrer & Harrer 1977).
c. Evaluative conditioning, a process involving eliciting an emotional response to a piece of music, based solely on its repeated association with other positive or negative stimuli (Blair & Shimp, 1992).
d. Contagion involves the induction of an emotion through music when the listener perceives the emotional expression within the music and then internally mirrors that expression (Juslin 2000). This mirroring leads to the experience of the same emotion, either through feedback from muscle activity at the periphery or by directly engaging relevant emotional representations in the brain.
e. Visual imagery involves the induction of emotion in a listener through the creation of visual images, such as a picturesque landscape, while listening to music.
f. Episodic memory refers to the conscious retrieval of a specific past event in the listener's life, which is prompted by the music (Baumgartner, 1992).
g. Musical expectancy involves the induction of emotion in a listener when a particular aspect of the music either disrupts, postpones, or fulfils their anticipations regarding music progression; emotions are particularly elicited when these expectations are violated (Meyer, 1956).
h. Aesthetic judgment involves a personal evaluation of the music's aesthetic value, determined by an individual's specific set of weighted criteria (Juslin 2013).

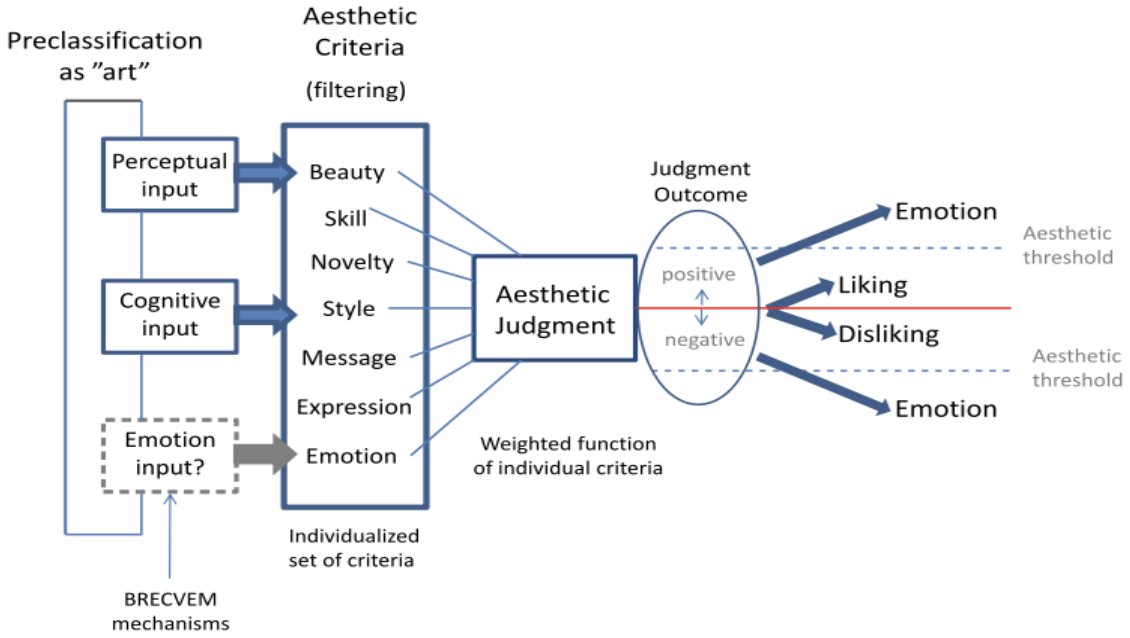

Figure 1. Schematic description of the aesthetic judgment process in music listening (Juslin, 2013: 235–266).

6. The experiment design: Interactive Virtual Heritage Exhibition

The above-described theoretical explorations have resulted in a creative outcome in the form of Interactive Virtual Heritage Exhibition titled 'Immersive Journey Around Hong Kong'. In this creative project, the represented Hong Kong natural heritages include Hong Kong UNESCO Global Geopark, Lantau Island, Lamma Island, Pat Sin Leng – 'Ridge of the Eight Immortals', and Hong Kong Island: Big Wave Bay (see Figure 2-6, all photographs taken by the author).

I will integrate musical and visual semiotics in my project. Musical semiotics are in the form of concrete-musical sonification applied to a futuristic music composition. It is created using datasets of water and air pollution and Indo-Pacific humpback dolphin from Hong Kong. The concept of sonification was originally defined from an engineering perspective. However, recently, researchers are increasingly integrating insights from electroacoustic music to enhance the effectiveness of sonification for science communication. Vickers and Hogg (2006) proposed the Aesthetic Perspective Space as a tool to bridge the gap between sonification and electroacoustic music. In this musical context, data can be mapped to musical elements like tempo, dynamics and 3D spatial form (Sawe *et al.*, 2020). This approach, which permits conveying the scientific meaning without transforming the main musical characteristics, is referred to as concrete musical sonification.

Visual semiotics are audio-driven in the form of 3D objects of Indo-Pacific humpback dolphins and flowers native to Hong Kong, utilized to enhance musically led exploration of the cultural heritage. These visuals are audio-reactive applied through various motion design techniques including visual effects and graphic design. This Interactive VH Exhibit combines surreal motion graphic and glitchy visuals incorporated in live action footage-VR 360 videos representing natural and cultural heritage of Hong Kong (see Figure 7 and 8).

The purpose of this research is to communicate the importance of environmental protection to the academic and non-academic audiences. Therefore, with the aim of carrying out public and digital humanistic actions, the creative outcome of this research in the form of interactive VH exhibition will be presented to the public.

In order to evaluate these theoretical designs, I will design user experience evaluation. To measure the emotional responses of the listeners to the music in VR, I will use MecScale developed by Juslin *et al.* (2010). Audience will be asked to fill out questionnaires based on BRECVEMA framework, a 15-item adjective scale. Additionally, to evaluate the perceived sense of presence in VR, I will use the ITC-Sense of Presence Inventory (ITC-SOPI). To assess the experience of awe in VR, I will utilize a single-item self-report measure on a 7-point Likert scale.

Figure 2. Lamma Island

Figure 3. South Bay

Figure 4. Hong Kong Underwater Tunnel

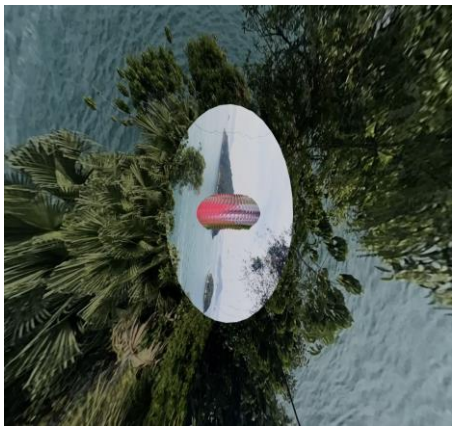

Figure 5. Hong Kong UNESCO Global Geopark *Figure 6. Green Island*

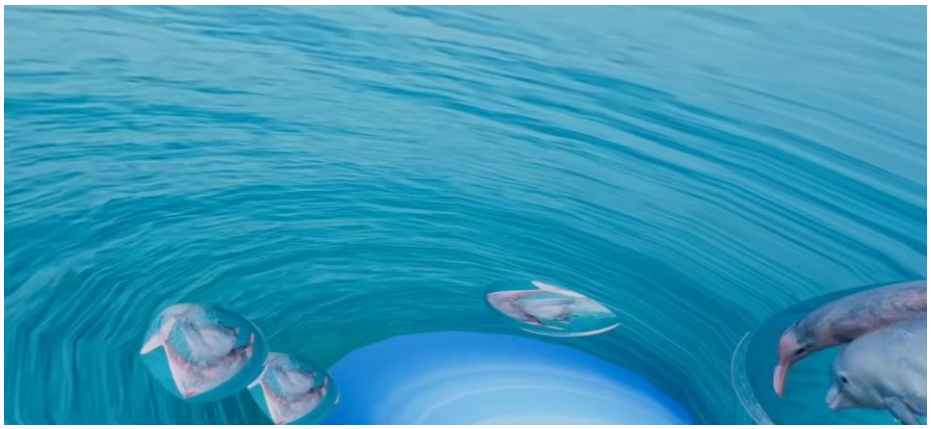

Figure 7. Audio-reactive 3D objects of Indo-Pacific Humpback Dolphins in South China Sea near Lantau Island

Figure 8. Work process in Cinema 4D

7. Conclusion

Since global environmental, cultural and social changes, representing a major threat to the future of the planet earth, pose serious challenges for humanity, it is crucial to communicate appreciation for natural heritage preservation. Therefore, the aim of this research is to create a realistic full-body VH experiences for the audience, utilising the potential of music and sound in VR to communicate environmental protection, and deliver enriching and long-lasting natural heritage experiences.

The conceptual framework of this research is based on new media theory and musical emotions theory based on BRECVEMA framework. Concepts of new media theory, and particularly Marshall McLuhan's concepts, were followed in the creation of the interactive VH exhibition and music compositions utilising the potential of music as a universal language to transmit the most important message to the audience, i.e. the appreciation and preservation of nature. In order to evaluate its achievement, i.e. creating an audio-visual VH environment that will allow intercultural learning, this creative project applies the concepts of BRECVEMA framework.

This creative artwork and user experience evaluation will enable delivering effective environmental communication through the music within immersive VR environment. By extending theory of musical emotions and BRECVEMA framework from the field of music, music psychology, and music cognition to the field of immersive multimodal VR, this project applies a great potential of sound perception for emotion activation in order to understand psychological aspects within immersive experiences. More precisely, this framework allows to understand how sound and music can evoke emotions within immersive environments and deliver message about the importance of nature protection.

Additionally, due to the fact that this project investigates cross-modal relationships between music, sound and nature in VR, its research outcome can contribute to various areas where spatial sound is applied. This may include natural heritage promotion, preservation and education, virtual tourism, art, film, video games, health care, real-time aviation, orientation and navigation.

Notes on Contributors

Mirjana Dokic is a composer, new media artist, researcher and violist based in Hong Kong, where, she is currently pursuing a PhD in Creative Media at the School of Creative Media (SCM), City University of Hong Kong, under Hong Kong PhD Fellowship Scheme. Her fields of research include electroacoustic music composition and performance for Virtual Reality, Virtual Heritage, Sound Art, soundscape composition and audiovisual composition. mdokic2-c@my.cityu.edu.hk (Primary Contact)

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