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The Scale of Immersion: Different audio-visual experiences exemplified by the 360° video *Secret Detours*

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Since the use of video became popular in the last five decades, the quality of the recorded images improved constantly, while broadcasting techniques thus advanced concurrently. From Omnimax to mobile screens, if panoramic, vertical or spherical, the author of the work is challenged to either fight for the intended format or adjust the work accordingly to presentation possibilities. Our recent *Secret Detours* may serve as an example, which was conceived as an immersive 360° video. Currently, we have developed a range of different versions in order to explore screening possibilities and adjusted not only the visual composition but as well the sound-design appropriately. We argue that the experience hugely varies, whether the work can be collectively viewed in a hemispherical dome, a cylindrical panorama, a panoramic LED video wall or by using VR glasses.

Media art. Spherical video. Immersive media. Virtual Reality. Video wall. Cylindrical panorama. Hemispherical dome. Surround sound.

1. INTRODUCTION

The initiative for this research in progress was the announcement of the refurbishment of a Chinese Garden in Singapore. Comparatively old for the 53-year-old city-state, the garden was built in 1955 as part of what was back then Chinese University. According to old photographs of this time, it was rather a wide-open space but contained already significant elements such as pavilions, the gate, bridges, stones and a memorial (Pookong & Kwai Keong 2013).

In the following decades, the huge trees became the dominant part of the garden, together with the beautifully arranged structure of pathways Figure 1). Captured images of the location show the beautiful contrast between a large palette of green and the red pillars of the pavilions as well as magnificent flowers in white, yellow, orange and red. However, being inside the construction of forking pathways, greenery and pavilions, it is a less pleasurable experience than it might be expected: The tropical humid and warm climate makes it almost impossible to linger there longer than necessary during the daytime. Biting mosquitoes diminish the pleasure in the cooler hours of the late afternoon and evening. And even in the morning hours, the noise of the adjacent highway overshadows the sound of birds and cicadas. Nevertheless, we as a group of educators, researchers and artists who work in different fields of immersive media, decided to explore the possibilities, how the experience of being inside the garden could be captured, recreated – and to some degree idealised – before the eminent trees have to make room for another road.

As no information was available in regard of the development plan and timeframe, we started with an immediate action to capture the garden as backdrop for a dance video and engaged Singapore-based choreographer Susan Sentler. Inspired by the layout of the garden, four dancers are representing the points on the compass and are dressed in vibrant colours. These were related to the cardinal directions in Chinese mythology: north is symbolised with a white tiger, east an

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azure dragon, south is represented by a vermilion bird and west by a black tortoise.

Based on the layout of the garden, we identified seven locations of particular interest:

- The centre pavilion in the middle of the garden as the starting point in which all directions and dancers appear equal
- The main gate in the south, with the attention on the vermilion dancer
- The north-west intersection with the black and white dancers searching for their direction
- The south-east intersection with the vermilion and azure dancers
- The memorial in the north, dominated by the white dancer
- A small garden in the west with the black dancer as lead
- A bench arrangement in the east with the azure dancer as protagonist

Although we were already considering different methods of recording, such as photogrammetry or laser scanning to build an even more immersive VR experience, 360° video allowed a much faster action and result. Both techniques for 3D representations were not only CPU- and manpower intensive, but as trees were at the time of filming an important component of the garden, the effort was foiled by difficulties to capture the moving foliage appropriately.

A *GoPro* setup allowed the footage to be stitched with a final result of 8K. As a result of the high resolution we have the possibility to explore a wide range of different presentation methods – and provide a new experience to engage with the work thanks to scale and format. New edits or at least different exports formats were required for *Oculus Rift*, *Google Cardboard/ YouTube*, *HTC Vive*, hemispherical and cylindrical environments, but also for a planar panoramic video-wall (Figure 2).

Figure 1: *The central section of Yunnan Garden on NTU campus, Singapore. The forking path structure invites to work with 360° environments.*

Figure 2: *Different to the immersive experience in a surrounding projection, the dancers on the planar panoramic video wall NEXUS accompany passers-by.*

2. DECISION FOR A 360° VIDEO

Based on Elke Reinuber's earlier research on the connection between choices and decisions in media art, she observed that screening environments which go beyond our peripheral vision immerse the viewer – but at the same time open up choices for the preferred viewing direction and composition. In her earlier work, *Decidophobia* (Reinhuber 2014), she was exploring particularly the representation of forking path structures in a panoramic environment. Encompassed by surrounding projections, the audience was challenged to decide in which direction to look. As the Yunnan Garden is a connection of forking paths and pavilions, also offering views in all directions, the desire to create a 360° production was almost obvious. However, at that point of time, no decision was yet made on the ideal form of presentation. During the production, we were discussing immersive environments and headsets, however never considered a planar panoramic presentation. Therefore most of the scenes engage the audience to look around. In particular scenes in which two of the dancers express their confusion in which direction to go, walking around and changing route, engage and bewilder the viewer. Apart from these scenes, we were mainly aiming to surround the viewer with visual impressions, no matter with which orientation to look. In the first scenes, all dancers appear equally from all four directions towards the centre and introduce their specific dance-moves. Subsequently, a main dancer is performing in her dedicated direction, North, East, South or West, while the other three move subtly in their orientation. Although directing the point of interest potentially through the action of the main dancer, there is sufficient to observe in all viewing directions.

2.1 Evaluation of presentation options

It seems only natural to watch the recorded and stitched footage firstly on a screen – as a flattened

sphere. However it becomes quickly obvious that the distorted video is not an adequate presentation format. The 'unframed' distribution of visual information appears too equable (Figure 3). Media players for 360° video frame a section of the work and allow to navigate through the film, similar to looking around, however without any physical engagement of turning the head or body – just like almost 25 years ago with QuickTimeVR (Chen 1995).

Figure 3: *Forking paths in the southeast, represented by the dancers dressed in vermillion and azure.*

Playing the same footage back on a mobile device with built in gyroscope – sensors which can monitor and control the position, orientation, direction, rotation, as well as angular motion by using Micro-Electro-Mechanical Systems (MEMS) – is already much more engaging. The mobile device serves as a frame and content can be discovered by moving the screen around.

2.1.1 VR headsets
The main parameters of a successful immersive viewing experience with VR headsets are, at this point of the technical development, three factors: The Field of View (FOV), the resolution of the screen, and the quality of the video being stereoscopic. The current version of the film *Secret Detours* is not stereoscopic but monoscopic.

Several options of VR headsets for mobile phones are available at the time of testing, from the most affordable *Google Cardboard* to plastic headsets such as the *VR Box* and the *Samsung Gear*. A cheap plastic headset such as the *VR Box* combined with a standard 4.7" screen phone will only offer approximately 65˚ Field of View (FOV), resulting in a very unsatisfying and far from life-size viewing experience with little immersion. In our comparison, the *Samsung Gear* with a large 5.7"-screen phone offered a FOV of 90˚–95˚, resulting in an acceptable viewing experience with a good immersion.

PlayStation VR offers 100˚ and PC based VR headsets such as the *HTC Vive* and *Oculus Rift* accomplishes an even higher FOV of 110˚. Although the film is monoscopic only and the *HTC Vive's* PPI (pixel per inch) resolution is lower than the mobile phone tested with the *Samsung Gear*, the additional FOV of the *HTC Vive* created an immediately more engaging viewing experience with subjects such as the dancers and objects like the pavilion appearing life-size.

2.1.2 Dome
Fulldome is an immersive dome-based video projection, which allows for a shared viewing experience of, depending on the size of the dome, a few dozen spectators simultaneously. While the exact level varies on the specific position of the individual viewer, the immersion is extremely high and satisfying. We evaluated the viewing experience of two different Fulldome setups:

(i) *Digitalis* dome with 6 meters diameter, a single projector with a 1.2K resolution.
(ii) *Fulldome.pro* dome with 7 meters diameter, a four-projector setup with a 3K resolution.

The 6m *Digitalis* is an inflatable dome, which requires the air compressor to constantly blow fresh air inside the dome, causing noise compromising the audio immersion negatively. The single projector is positioned on the floor in the centre of the dome projecting upwards (See Figure 4). The resolution is limited by the single projector's vertical resolution of 1200 pixel, causing the image to appear a bit too soft. The limitation of the resolution is not as obvious with abstract images or motion graphics, but with the live-action content of *Secret Detours* the softness is unsatisfying. The dome is best suitable for content playing at the zenith above the audience with a viewing position lying on the floor looking upwards. With the film *Secret Detours* designed around the four cardinal directions, we can conclude that a single projector setup is not suitable to create a satisfying immersive experience.

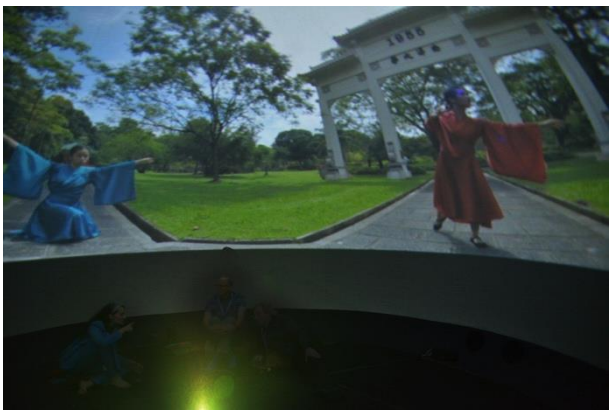

Figure 4: *Larger than life-size presentation in the Digitalis dome with one projector invites one to sit down and observe.*

The 7m *Fulldome.pro* dome does not require an air-compressor but uses a scaffolding set-up; still,

the sound experience is severely compromised by the attached air condition. The four-projector setup allows a maximum resolution of 3K, almost 9 times higher than the *Digitalis* single project dome. However, at the time of testing we could only evaluate a 2K version, still 4 times higher than the *Digitalis* dome. The dome is angled at approximately 10˚, allowing space for the dome's entrance at one side and content below the equator at the opposite side, creating a preferred viewing direction towards the lower side of the dome. Figure 5 shows the 180˚ fisheye image for the angled Fulldome: The dancer at the top is mostly cut off by the dome's entrance door while the dancer at the bottom is framed in full size due to the additional 10˚ below the equator.

Figure 5: *Fisheye image for angled Fulldome.*

Figure 6: *Presentation of the work in a 7-meter Fulldome with four HD projectors.*

We can summarise, that the additional resolution of the *Fulldome.pro* dome enhanced the viewing experience significantly. The dome space feels comfortable and large enough for a satisfying shared experience. However, as the dome is angled towards one preferred viewing direction, films with relevant content at all four directions must be considered incompatible as they almost entirely scarify one of the four viewing directions.

2.1.3 Cylindrical panorama

Less common are immersive cylindrical panoramic environments such as the permanently installed *PanoramaLab* at ZKM Karlsruhe, the *iCinema* and *EPICentre* at UNSW Sydney or temporary ones as set up for the 'Time Around Space' conference at Plymouth University in 2013. Although floor and ceiling are not covered with projections, the viewing experience is convincing: the spectator's peripheral vision is fully covered, no immediate distortion is recognisable, unlike to a small dome. The audience usually walks in, looks around into different directions and the environment engages a mobile spectatorship (Skoller 2005, p.176) as they provide sufficient space to move around. The desire to sit down and look up is not as prominent as in the Fulldome.

The resolution and with it the level of detail is usually very convincing for a normal viewing distance due to the necessity for multiple projectors.

As in the case of the *EPICylinder* in Sydney, the display with currently the highest available resolution consists of an array of 14 full-HD screens in width and 4 in height, adding up to almost 120 millions of pixels, the resolution proves to be a true challenge for the presented works. Shown as part of the programme of 'Visualisation matters today' in November 2017, *Secret Detours* could not be presented satisfyingly on full screen, despite its 8K resolution. However, as a result, all invited works shared the panoramic display as a whole, similar to salon-style hanging – a rather media-multitasking approach than an immersive experience. For this presentation, we also decided to neglect the audio for obvious reasons.

A test-setup in the *PanoramaLab* at ZKM Karlsruhe, which is significantly smaller than the above-mentioned installation, was very engaging as the surrounding actors and the garden itself appeared life-size. However, the height of the screen reminds the spectators of the projected images and is less immersive than the taller screens (Figure 7). For a projection of an earlier work in Plymouth, the resolution was significantly lower due to the usage of XGA projectors and at the same time, the diameter of the cylinder was twice as big, which made the projection look softer and slightly faint due to the distance. Nevertheless, with the height of the projected image, the audience quickly ignored the technical deficiencies. The impression of the work is similar to the projection in the Digitalis dome as the dancers surround the spectator.

Figure 7: *The shared experience of viewing Secret Detours in a cylindrical panorama – the ideal set up for the mobile spectator.*

2.1.4 Panoramic video-wall
The panoramic video-file was subsequently re-adjusted to be showcased on the *Media Art Nexus* (MAN) NTU Singapore, a 15m by 2m large LED media wall-exhibition space (Figure 2) in a narrow walkway connecting two buildings, with high traffic. Although the same footage was only moderately readjusted, the impression of the work is almost not comparable. Passers-by walk along the captured greenery and are accompanied by the dancers. Hardly anyone stops and watches the whole piece, however the life-size actors get a lot of attention while the vibrant colours brighten up the greyish corridor. The term immersive does not be apply to this form of presentation at all, however the engagement between spectators and display appears obvious.

2.2 Re-Editing for different screens

2.2.1 Converting for Fulldome
Presenting the 360˚ spherical film in a hemisphere dome requires the film to be converted to a 180˚ fisheye format. The main issue of the conversion process is the obvious fact that everything below the equator of the spherical film would not be visible in a 180˚ hemisphere dome.
The *Secret Detours* film was not designed for a dome projection originally. Specifically, the performance has not been framed during the shooting to appear in the upper hemisphere only; the dancers utilize the entire space and floor in front of the camera.

As an example, in Figure 8, the performers face the camera inside the pavilion, while the camera height is approximately on eye-level of the dancers. The camera height represents the equator in a spherical image, and as everything in the lower hemisphere will be lost in the conversion to the 180˚ fisheye dome format, most of the dancers' performance would be cut off (Figure 8, fisheye image 1).

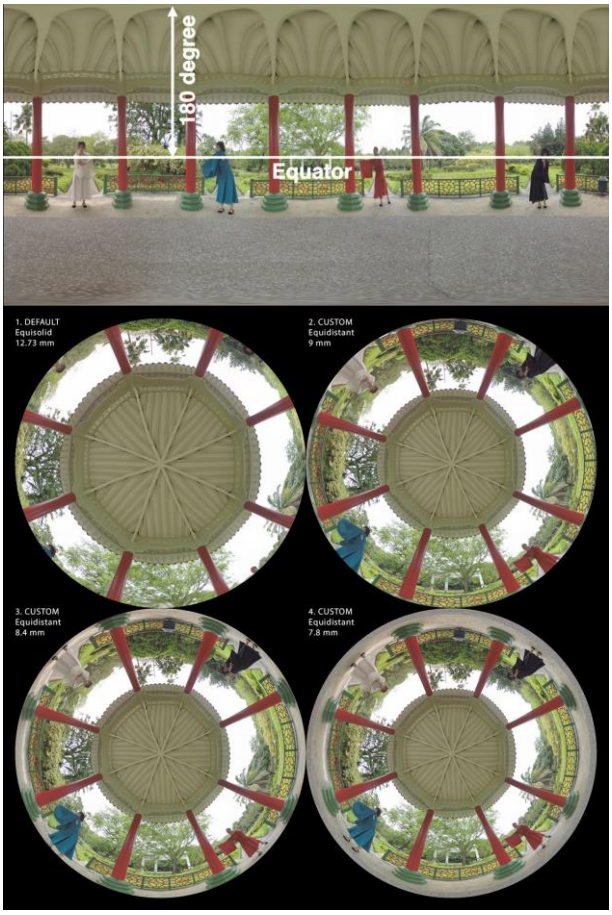

Figure 8: *Conversion from spherical to fisheye format.*

The conversion process in *The Foundry's CaraVR* software with the *Spherical Transform* tool allows specifying the algorithm of the fisheye projection method and the focal length of the projection output camera. To frame the performance into the upper hemisphere, the focal length had to be adjusted. Figure 8, fisheye images 2-4 demonstrate the effect of lowering the focal length values. The focal length adjustment can be understood as compressing a viewing angle of i.e. 220˚ into a 180˚ format. Such focal length manipulation will introduce a vertical distortion, most obvious in the appearance of the height of objects being compressed. Depending on the specific projector setup of the dome, a FOV adjustment option might be available in the projector setup to vertically stretch the image and compensate partly for the vertical compression caused by the conversion.

2.2.2 Editing for panoramic screens
As there is no general standard for cylindrical panoramas, the aspect ratio and resolution differ for all screens. For our test installation at ZKM, we simply cropped off the top and bottom part from the spherical movie and adjusted the horizon. As seen in the two scenes in Figure 9, only a small strip of the whole movie remains and the focus is merely on the dancers than on the garden. In particular the tree canopies, which are an essential part in the

dome projection, and the intersections, well visible with the headset, are lost.

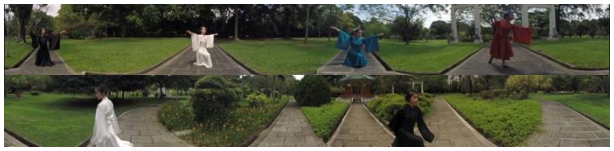

***Figure 9**: Panoramic planar still of Secret Detours for the NEXUS video wall.*

The panoramic version for the video wall allowed slightly more space at top and bottom with its aspect ratio of 8:1. Different to all other set-ups, instead of allowing the viewer to look around, the image was clearly determined by a static frame and the main editing decision was defined by positioning the dancers appropriately. Dissolves were used to transit softly between each scene, with particular attention to connecting elements, such as the dancers or pathways.

***Table 1:** Current screening formats of Secret Detours.*

Display	Resolution		
	Width in px	***Height in px***	***Geometry***
Original footage	*7680*	*3840*	*Spherical*
VR headset	*7680*	*3840*	*Spherical*
Cylindrical panorama	*5248*	*608*	*Cylindrical*
Panoramic LED video wall	*3840*	*480*	*Planar*
Fulldome	*2048*	*2048*	*Hemispherical*
Mini-Fulldome	*1200*	*1200*	*Hemispherical*
Flat Screen, VLC, GoPro or YouTube	*Screen resolution*		*Planar, scrollable*

3. SOUND FOR ALL OCCASIONS

The 360° video has to date been presented in dome projection, flattened panoramic 2D and headset/Google Cardboard 360°. These different modalities invite discussions on aesthetic and technical considerations within the conception of sound as part of emergence theory (Garner & Grimshaw 2015).

In designing the sound world for this work there were several fundamental questions that were considered. In what ways will the sound and/or music be experienced by the listener (i.e. headphones or speakers)? How does the sound and/or music contribute to or define the narrative structure of the work? What level of immersion is desired and what does the sound world consist off? What is our desired audience reaction to the work and what do we know of their expectations?

Putting the technical considerations to one side, let's consider the aesthetic decisions and what informed them. Due to time constraints and the need to shoot the 360° footage prior to redevelopment work commencing in the garden, sound was not seriously considered until the post production stage of the work. So the dancers did not hear, and so were be unable to react to, the sound that will accompany their performance. This atypical workflow was necessitated by the compressed time schedule and it structures many of the aesthetic decisions that followed.

Being a dance work, music was the first sound element developed, with considerations of instrumentation, melodic and harmonic content and form are informed by the image content and the context of the work. Although Yunnan Garden is in predominantly ethnically Chinese Singapore it was decided that the music should only subtly suggest a grounding in this culture. We did not desire for the music to evoke any strong cultural associations but to merely hint at a cultural context. The main instruments solo flute and solo oboe as well as the harmonic language, where employed with this in mind.

The relationship of the music to the dancers was structured in part by the sub optimal workflow. Since the dancers weren't reacting to music it was necessary to create music that appeared to be reacted to, as well music that reacted to the dancers. A two-sided relationship needed to be forged to form a coherent narrative relationship between the dancers and the music. This was achieved through loose synchronisation of dance and musical gesture in the temporal domain, and with the kinaesthetic properties of the dance informing the structure of the melodic lines of the solo instruments. Fast movement is accompanied by rapid melodic lines, slow movement by sustained or slowly moving ones.

Through this union, the prevailing aesthetic becomes almost meditative or ritualistic, and it is further enhanced with the addition of percussion instruments such as gongs and claves.

Atmospheric sound forms the underlying ground to the figure that is the music. It was not desirable to use a recording of the actual garden for this, due to the presence of a nearby freeway and the noise associated with it, so recording of a similar, less noisy garden location was made and used for this purpose. Although the recording of the garden would be considered as diegetic sound, its function is primarily to help facilitate a sense of immersion, of presence in space. It suggests a larger world beyond the confines of the image but there was no attempt at any kind of diegetic realism. It is as

Chion (1995, 95) might describe, a "rendered" sound.

No other diegetic sounds are used in the soundtrack, although the music and it's strong narrative relationship with the dancers, might well be considered as inhabiting the same narrative space, and so Winter's (2010, 243) use of the term intra-diegetic might be appropriate. This somewhat simple sound world was the result, in part, of the technical considerations of audio playback.

During the design of the sound for *Secret Detours* the expected projection format was dome presented 360° video. Unlike in traditional film, there is no standard for sound reproduction in dome projection and so the sound reproduction specifications where essentially unknown until the specific screening location was determined. The amount of channels and speakers available and their placement in the dome essentially determines the spatial design possibilities. A large dome with multiple channels allows for a greater degree of sound localisation than a small dome with fewer channels. Also of consideration is that the acoustic properties of the concave dome interior work against accurate sound localisation as sound reflections propagate to the centre of the dome. Added to the technical considerations is the ambient sound environment of the dome. Fans from projectors or from pushing air to inflate the dome can add a considerable amount of noise to the ambient noise floor and this can often mask quiet sounds in the sound track.

The technical realities of the dome projection had a considerable impact on the realisation of the sound design. A limited use of sound localisation was employed in the sound design for the dome projection version of the work since it was unlikely detailed sound localisation could be reproduced.

Presented in four-channel surround sound, the music and ambience are placed equally in all four channels with the exception of some instrumental panning. A limited dynamic range was utilised so the average output volume could be maintained at a level to avoid masking by the ambience noise of the dome. These factors also contributed to a limited sense of immersion when the work was screened, as a coherent perceptual experience was difficult to obtain.

The sound reproduction specifications for the panoramic 2D version were known in advance as it was site specific. A 5.1 surround speaker system was installed with the LED panoramic video wall consisting of standard left, centre, right, left surround, right surround and a subwoofer. Location of the video wall in a quite narrow open corridor (see Figure 2) led to a less than optimal placement of the rear speakers and they are mounted directly facing the screen at 180° and rather than the preferred 110°. Located in a high traffic area adjacent to multiple food vendors and other noise sources, the listening environment was to put it bluntly, terrible. Once again a limited dynamic range was employed to combat the restrictions imposed by the ambient noise. This viewing location did not allow for any real sense of immersion.

This mode of the work requires to viewer to look at a screen and so face in a single direction so a standard cinematic use of the 5.1 sound field was employed. Music is presented predominantly in the front three channels with some presence in the rear surround channels and the ambience is presented equally in all channels.

The more controlled sound reproduction conditions of headphones, used for the VR/Headset version of the work, afforded much greater possibilities for spatial sound design and dynamic range. Binaural modelling allows for quite accurate localisation of sound in a 360°sound field so for this version the solo musical instruments were mapped quite closely to individual dancers, binding them together in the narrative. These associations change as the work progresses and help suggest narrative evolution. The increased dynamic range available allowed the use of subtle, delicate and distant sounds. Wind and rustling leaves were added and mapped to image, gongs positioned as off screen diegetic sounds, like bells just beyond view. A richer and more dynamic soundtrack creates a greater sense of immersion in this version of the work.

4. CONCLUSIONS

To conclude, we suggest that all different modes of presentation have their own right of existence. The requirements differ hugely and with it the experience. Although audio and visuals complement and enhance each other, the perception according to the presentation cannot be generalised.

Dome environments, allowing a shared experience and convincing life-size projections, might not be the ideal set up for audio due to various sources of ambient noise.

In the cylindrical panorama, the audience can move freely within the space and it is usually in a dedicated environment in which also the conditions for surround sound are taken into account. With arrays of multiple projectors, a high resolution and satisfying level of detail can be achieved. Projector fans produce still noise, but as most of the

panoramas are open to the top, it cannot be compared to the noise in a dome. However, as specifically experienced in the garden scenes with overwhelming tree canopies, the whole upper part of the spherical video is lost.

However, discussing the possibilities to represent the experience of being inside a garden, not only our visual and auditory senses need to be taken into account. Gardens can leave an intense olfactory impression. However at this stage, we were focussing on capturing an audiovisual impression.

VR Headset and headphones might be currently the best compromise as they offer a standardised user experience with known and predictable parameters for image and sound reproduction.

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