Different Layers of Reality. A Retrospective Evaluation on diverse possibilities for digitally preserving memories of the Yunnan Garden as an Immersive Experience

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Abstract

This paper offers an in-depth evaluation and future outlook of the representation of Singapore's Yunnan Garden, with a central focus on various methods to create an immersive experience. The methods explored include 360-degree video, photogrammetric capture, and detailed photorealistic VR reconstruction. We critically assess their effectiveness and potential in the preservation of cultural and natural heritage in the digital world. The incorporation of interactive elements and the inclusion of motion capture of performers are also thoroughly examined. Challenges faced during implementation are discussed and solutions proposed for future attempts. The paper concludes with an exploration of the current approach to working with Gaussian Splatting as a future outlook. The research goes beyond the objective of preservation by reconstructing the former garden into a virtual cultural heritage application. It delves into diverse narrative and aesthetic experiments, aiming to create artistic interpretations that engage the audience. This endeavour challenged the project team to explore novel visual and aural forms of representationr.

Keywords

Digital Ecologies, Digital Preservation, 360-degree Video, Immersive Experience, Virtual environments, Photogrammetry, Interactions, Human and Non-human Agents, Gaussian Splatting.

Introduction

The Yunnan Garden, a cherished tropical landmark in Singapore, has recently undergone major refurbishment. This transformation led to the loss of its structure and some original elements, prompting us to explore various immersive technologies to digitally capture, preserve, and interpret the garden as it once was. This paper delves into the methodologies employed, including panorama photography, 360-degree video, photogrammetric capture, and near-photorealistic 3D reconstruction for Virtual Reality (VR), providing a comprehensive digital portrayal of the pre-refurbished state of the garden.

The starting point for this project was the question how the choices we have in life and the decisions we make may be communicated in an artistic project. The different versions to represent the Yunnan Garden echo the real-world experience of navigating through a garden with forking paths, where visitors choose their own routes and directions. These structures provide a metaphor for the choices and decisions we make, adding a philosophical layer to the VR experience. Meanwhile, 360-degree media does not only demand the viewer to choose a viewing direction but also offers a comprehensive view of the garden, capturing its landscapes in their entirety. This method allows for interactive exploration, giving the audience control over their perspective and enhancing the immersive quality of the experience.

As a core team of three, we brought together our expertise working with different techniques, imaging, conceptualisation, 3D rendering, motion capture and sound design. To add life-action to the garden, we engaged a choreographer and dancers for two versions of the project and were supported by student assistants.

Panorama photography was one of the first methods used in the project, providing a broad perspective that can be interactively explored in a digital environment. Next, we employed 360-degree video, using a specialised omnidirectional camera, to capture the immersive nature of the garden environment.

Photogrammetric capture was yet another critical technique used in the project, to create highly detailed and accurate 3D representations of specific elements within the garden. Lastly, we created a complete near-photorealistic 3D reconstruction for a virtual reality (VR) experience, which invites users to traverse the garden in a highly immersive way. In addition to these techniques, we also incorporated motion capture of dancers as point clouds, allowing users to interact with dynamic elements. Finally, in a meditative experience users were encouraged to explore the greens while contemplating introspective questions.

Each of these methods was chosen for its potential to contribute to a comprehensive and immersive digital representation of the Yunnan Garden while adding narrative elements and structures, which were related to the concept, layout and location of the garden. By combining these techniques, we were able to preserve a detailed record of the garden as it once was, allowing future generations to

experience and appreciate this significant cultural and natural heritage site through a series of artworks.

Approaches and challenges for capture and representation

The methodology for this project involved a multifaceted approach, leveraging a variety of digital preservation techniques to capture and recreate the Yunnan Garden in its original state. Each of these methods added a unique perspective and provided different layers of detail to the virtual reconstruction.

1. Panorama Photography:

This technique was used to capture wide-angled, high-resolution images of the garden. The panoramic views provided comprehensive visual data, granting an encompassing perspective of the garden's landscape. This method was instrumental in referencing the broader landscapes of the garden in their original state. With 360° cameras, the garden could be captured fully spherically with one click, a significant advantage compared to panoramic images stitched from multiple files. The low resolution is still sufficient for projections, views in the headset or as in our case – adding a background to the horizon of the recreated landscape and to keep a record of views from the garden. In an earlier project, *Decidophobia* (2012), the aim was to combine individual images of forking paths with multiple vanishing points to a large printed panorama and to be ultimately animated and screened in an immersive environment. With no central perspective to focus on, the viewers were encouraged to reflect on their choices.

2. 360-Degree Video *Secret Detours*:

With this method, an omnidirectional camera array was used to record a view in every direction simultaneously. This technique is particularly useful for creating an immersive experience for users. It enabled viewers to control their viewing direction, exploring the garden as if they were physically present. In the short omnidirectional video *Secret Detours* (2017), four dancers represent the cardinal directions through colours and movements related to animals in Chinese mythology – North, South, East, and West. This creative decision enables an exploration of spatial orientation in the 360-degree film. The dancers' movements and interactions with each other and the environment contribute to the overall narrative of the piece, inviting viewers to examine significant locations of the garden within the immersive experience and enhances the sense of directionality and spatial experience for the viewer. Each dancer's performance plays a crucial role in shaping the viewers' perception of the space and their journey through the virtual garden, adding depth and context to the visual elements of the film. Movements of the performers were also recorded as motion capture and returned in the VR version *Flux Garden*.

3. Photogrammetric Capture *Gone Garden*:

This advanced technique involves taking a series of overlapping photos of an object, then using software to interpret the depth and shape of the object to create a 3D reconstruction. The use of photogrammetric capture allowed for the creation of highly detailed and accurate 3D representations of specific elements within the garden, such as the monument, stone sculptures and unique tree trunks.

Aside from employing photogrammetry to capture these specific structures, an aerial survey was also carried out to photograph the entire garden landscape. However, since these photos were exclusively taken with a downward perspective, the dataset proved significantly inadequate for generating an accurate 3D reconstruction of the garden. Processing the constrained dataset through photogrammetry led to a reconstruction of very low resolution, wherein details like trees were transformed into circular masses, forming a somewhat abstract landscape (Figure 1a and b).
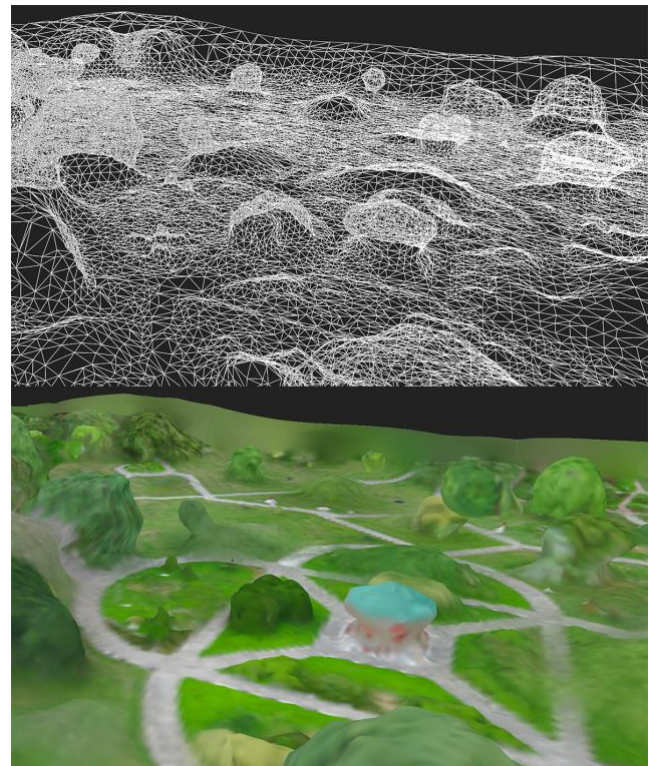

Figure 1a and b. Result from drone capture for photogrammetry of the Yunnan Garden. ©The authors.

In 2018, the condition of the garden was characterised by the coexistence of preserved sections and those that had been removed. This circumstance influenced our decision to explore a blend of abstract and realistic elements, encouraging us to integrate a low-resolution 3D reconstruction with a precise recreation. The core of our visual representation relies on the dataset derived from the garden itself – a technically imperfect reconstruction stemming from insufficient data, typically subject to
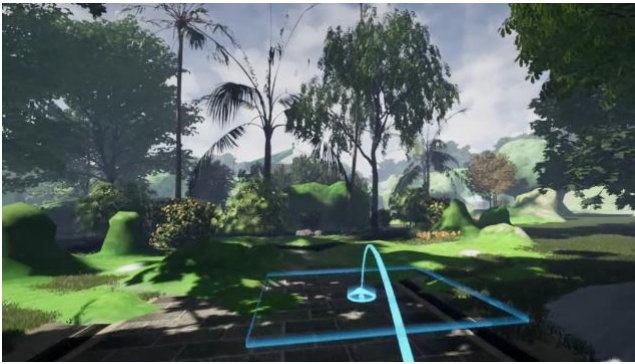
dismissal. By meticulously incorporating trees and flowers to match both their appearance and positions, our visual representation embodies a fusion of reconstruction and artistic interpretation.

Figure 2. Impressionistic room-scale VR experience Gone Garden, based on the photogrammetric capture. ©The authors.

As outlined in our previous research [8], our objective was to enable viewers to experience and explore the impressionistic fragmentation of the garden, serving as a representation of memory and an interpretation of its vanishing.

4. Near-Photorealistic 3D Reconstruction for Virtual Reality (VR) *Yunnan Garden VR*:

The most comprehensive method involved creating a complete near-photorealistic 3D reconstruction of the garden for a VR environment. Advanced computer graphics techniques were used to create an extremely detailed and visually accurate digital replica of the garden. This VR experience provided a highly immersive platform for users to explore the garden, enabling them to move and look around as if they were actually there.

Figure 3. Overview of the 3D reconstruction in Epic's Unreal Engine ©The authors.

Our process of generating a 3D approximation of the garden commenced with the reconstruction of the ground topology. This involved accurately plotting the positions of trees and establishing the layout of walkways using a detailed topographic map in conjunction with an orthographic photo.

Relying on both the topographic and orthomosaic maps, we meticulously reconstructed the precise 3D topology of the ground floor. Subsequently, we strategically placed 507 markers representing 16 of the most common tree species.

To populate the garden with vegetation, we adapted tree and plant assets to align with the specified species, positioning them according to detailed maps. The one-kilometre path structure encompasses the primary path along the vertical axis, extending between the gate and monument, as well as horizontally connecting four outer pavilions and featuring the distinctive interlocking circular paths around the main pavilion, known for their "knotted" configuration. Our focus in recreating the garden centred on the central area surrounding key structural elements: the entrance arch, central pavilion, and the memorial monument.

After exploring photogrammetry-based approaches, we determined that remodelling based on photogrammetry, coupled with the use of high-resolution photographs as material textures, was the optimal method for the main structural elements – the monument, arch, and pavilions. Although considered approximate recreations, the 3D models of these structures exhibit a remarkable level of visual fidelity.

Figure 4. Entrance gate in the photorealistic room-scale VR-experience Yunnan Garden VR. ©The authors.

5. Motion Capture of Dancers as Point Clouds *Flux Garden*:

Expanding on the groundwork laid by *Gone Garden* (2018), which initially aimed to create an impressionistic depiction of the garden through a 3D reconstruction process with limited data, *Flux Garden* (2020) takes it a step further by introducing abstract dancers into the virtual environment, adding an extra layer of engagement. The conceptual underpinning stems from the observation that the construction of the new garden led to the removal of numerous unique tropical trees. In our interpretation, the abstract dancers serve as a symbolic reincarnation of these felled trees. The abstract landscape, characterised by roundish blobs, represents fragments of the trees reconstructed in 3D through photogrammetry with insufficient data. The resulting environment is a product of experimental blending of abstract and realistic elements, as we merged a low-resolution 3D reconstruction with our

precise recreation, resulting in an impressionistic, dream-like remembrance of the garden.

A Vicon motion capture system was employed to capture the dynamic movements of expressionistic dance performances. These recordings were then utilised to generate real-time particle simulations that enveloped the dancers, creating immersive 3D representations. (Figure 5) This incorporation of abstract point-cloud performances introduced a dynamic and interactive dimension to the overall experience. Users were not only able to survey the garden but also engage with the virtual dancers. Beyond the preservation focus of the *Yunnan Garden VR* experience, *Flux Garden* provides an interpretation of heritage with the intention of fostering emotional engagement among the audience.

Figure 5. Real-time particle simulation based on performance capture in Flux Garden VR. ©Respect Copyright.

6. Interactive Elements *Garden of Changes*:

In fusing garden architecture with the ancient Chinese manual of divination, the I Ching, in this Virtual Reality platform, *Garden of Changes* proved to be a unique project. It stands out due to its interactive and immersive nature, allowing users to physically navigate the VR recreation of the Yunnan Garden, make decisions at various intersections, and engage in a process of self-reflection. The user's interaction at decision points played a significant role in the experience. They were invited to walk through the greens while contemplating introspective questions and tossing coins at intersections. Users are encouraged to pose a question at the entrance gate to the garden and seek answers while exploring the garden, thus transforming their VR experience into a personal journey of introspection. The choice of direction for tossing a coin at chosen intersections generates broken and solid lines, combined to a hexagram for an iChing reading at the final station of the tour, a Chinese monument. While Borges' short story of "The Garden of Forking Paths" served as the main source of inspiration for the engagement with forking path structures, this interpretation connects closest to the impression of an infinite "network of diverging, converging and parallel times", symbolised through the pathways in a garden.

The *Garden of Changes* aims to slow down the pace of interaction commonly associated with VR, inviting users to

ponder, reflect, and appreciate the green reconstruction of the vanished trees, closely mirroring the experience of being in the actual garden itself.

7. Application of AI for 3D representations:

As of the current writing in 2023, our team is actively exploring the application of 3D Gaussian Splatting as a novel method of representation. Notably, Gaussian Splatting yields results akin to those obtained through Radiance Field methods (NeRFs). However, it distinguishes itself by offering a faster setup process, quicker rendering, and comparable or superior output quality. Our approach aligns with the methodologies elucidated by Kerbl, Kopanas et al., as detailed in their notable SIGGRAPH paper [7].

To conduct our investigations, we leverage existing datasets acquired in 2017, predating the garden's refurbishment. These datasets include photos captured via drone and ground survey, showcasing various elements such as the monument structure. Our objective is to compare the 3D reconstruction achieved through photogrammetry with the volume rendering capabilities of Gaussian Splatting.

Preliminary tests have yielded promising results, with Gaussian Splatting demonstrating an enhanced level of detail and visual fidelity, as depicted in Figure 6. Given that both NeRF and Gaussian Splatting visualisations exhibit particular promise in environments characterised by intricate details, such as our garden (Figure 7), we are committed to further evaluating additional footage from our original captures in future analyses.

Figure 6. Comparison of photogrammetry (left) and Gaussian Splatting (right) from identical dataset. ©The authors.

Figure 7. Gaussian Splatting test with high level of detail of plants. ©The authors.

Evaluation and discussion

1. Artistic interpretation vs heritage preservation:

In the "Handbook on the Economics of Cultural Heritage" (2015), Rizzo and Mignosa emphasise the significance of narrative involvement for the success of Virtual Heritage applications. Our perspective aligns with this idea, contending that developing an audio-visual interpretation of heritage can effectively enhance audience engagement and involvement. Our approach is rooted in artistry, as we blend realistic and abstract elements of the garden to create a novel work. We have deliberately kept the subjective-aesthetic design of the immersive space very subtle, so that the impressive involvement with a 360° experience is not overwhelming from the outset due to challenging visuals. Since it was important to us to preserve the cultural heritage throughout the entire project, with the professional guidance of the experts consulted and taking into account the scarce archival material, we only made very careful use of our artistic licence.

Beyond the preservation focus of the Yunnan Garden VR experience, *Flux Garden* provides an interpretation of heritage with the intention of fostering emotional engagement among the audience. The same can be said about *Secret Detours*. Instead of presenting still photographs of different locations in the void garden, the inclusion of performers as an additional element enhances the attractiveness significantly and provides a sense of scale and place. While discovering the features of the garden at one's own pace, the interactive aspects of *Garden of Changes* suggest an auxiliary meaning of the intersecting path structure of the park with the invitation to take an inward turn. *Gone Garden* stands out and offers rather a representation on an emotional level, reminiscent of the fragmented memory of the green area as it once existed. The novel application of Gaussian Splatting delivers a highly realistic representation from historic images with a low compute. For this approach, we need yet to investigate how adjunct elements may be included.

2. Levels of realism:

Based on the extensive data material that we collected during the comprehensive digital inventory when the garden was still intact, we have found different ways of using the material in the most appropriate way for our individual projects, depending on the style.
- Photographic Realism (Photo/Video): In *Secret Detours*, this level of realism is achieved through the use of photos and videos which give an accurate and direct representation of the real world. This method is highly effective for documenting existing conditions and events as they occur in real time.

- Semi-Realistic 3D Re-creation (Photogrammetry / 3D Modelling): This involves the use of techniques like photogrammetry and 3D modelling to create a semi-realistic digital representation of the subject. While not as direct as photographic realism, these models can provide a good approximation of the real world.
- Photorealistic 3D Reconstruction (Scan/Nerf/Gaussian): This level of realism involves the use of advanced scanning techniques and algorithms to create a photorealistic 3D model of the subject. These models are often indistinguishable from the real world and can provide a highly immersive and realistic experience for users.
- Non-Photorealistic Representation / Abstract (Mix of Insufficient Data and 3D Modelling): In *Gone Garden*, this approach is used when data is insufficient for creating a photorealistic model. It involves the use of 3D modelling to create an abstract representation of the subject. While not as realistic as the other methods, it can still provide an interesting and engaging user experience. For all the different approaches, sound played an important role.

Compared to the representation of the garden as 360° video, all other approaches permit the stereoscopic perception of the garden and even the possibility to walk through the room-scale VR experience. Comparing the video Secret Detours with Gone Garden, the level of realism differs significantly. The monoscopic real-video transports the viewer in the exact location of the omnidirectional camera set up and allows in this position to look around, up and down, following the movement of the dancers, which have been strategically positioned in four directions, while encouraging the viewer to turn around and follow them. Details of the garden, plants and the performers are well visible in this real-life footage. Gone Garden however lacks precise features but provides an even better sense of place. Both versions had been presented at the Beyond Festival at ZKM Karlsruhe in 2018, the video in the immersive cylindrical panorama environment and Gone Garden with a VR headset, providing a three-dimensional sense of the space and allowing one to walk around.

3. Sound as an essential component:

The exploration of the digital representation and preservation of a culturally relevant site also concerned aspects of intangible cultural heritage, specifically soundscapes. Although beyond the scope of this discussion, soundscapes as intangible cultural heritage were a consideration when designing the sound of the experiences discussed. The question of what should the garden sound like was important but equally was "when" should the garden sound like. When first laid out, the garden was in a rural area surrounded by agricultural land and close to a village or kampong. Now the garden is boarded on one side by a major expressway and a sprawling university campus on the other. Our approach was to render a soundscape as if all sound emanated from within the garden, so the ever present drone of traffic was excluded as were other anthropomorphic sounds. Ambisonic recordings from parks in Singapore were created and used as the base of the

soundscape. Additional recordings, including of birds endemic to the region, were added. This formed the basis for all research outputs and were modified for the different contexts. Music plays an important role, specifically in *Secret Detours* and *Flux Garden*. Both works feature dancers, *Secret Detours* has live dancers who are accompanied by live instruments such as flute, oboe and gongs which invoke the ritualistic nature of the piece and fill the whole sound field. *Flux Garden*'s particle system dancers move to more synthetic sounds that are tied to specific locations, leading users to find the mesmerising figures hidden in the landscape. In this example each dancer is accompanied by a different piece of music which is only heard when in proximity to their location. This encourages exploration of the whole garden, a siren call leading us ever forward. A compelling sound world is fundamental to the immersive experience and to foster engagement with the virtual landscape. It also has the potential to be a time capsule of intangible cultural heritage.

4. Experience: Realism vs Emotional Experience

In the context of digital preservation and representation of heritage sites, the balance between realism and emotional experience is crucial. Realism, achieved through methods such as photographic capture, photogrammetry, and advanced 3D reconstruction, allows for a highly accurate representation of the site. This level of detail can provide a deeply immersive experience, transporting users virtually to the area and allowing them to explore it as if they were physically there.

However, an emphasis on realism should not overshadow the importance of emotional engagement. Creating a connection to the artefacts can enrich the user's experience, making it more personal and meaningful. This can be achieved through various means, such as incorporating narrative or interactive elements, performance, music, and abstract artistic interpretations. Even when the representation is not fully realistic, such as in the case of abstract or impressionistic renderings in *Gone Garden*, the involvement of the user can be elevated if these elements are thoughtfully integrated.

In essence, while realism can enhance the immersive quality of the digital representation, the emotional experience can deepen the user's connection to the heritage site, resulting in a more impactful and memorable experience.

Conclusion

In conclusion, this project has delved into a range of methodologies aimed at digitally capturing, preserving, and representing the Yunnan Garden. Each of these methods has

brought distinctive perspectives and varying levels of detail to virtual reconstructions, leading to different forms of digital representations.

Among the explored methodologies are panorama photography and 360-degree video. Both of these techniques have been instrumental in capturing comprehensive views of the garden, providing users with a sense of realism and a broad perspective of the garden's landscape.

We have also explored the potential of photogrammetric capture, which allowed for the creation of highly detailed and accurate 3D representations of specific elements within the garden. This technique proved to be useful to a greater degree for capturing intricate details like the scholar rocks and unique features of the garden that contribute significantly to its identity.

The paper also looked into the potential of near-photorealistic 3D reconstruction in Yunnan Garden VR, adding motion capture of dancers as point clouds, and interactive elements. These methods have enabled us to create an immersive, interactive, and highly detailed digital replica of the garden, fostering an active exploration and emotional connection with the garden for the users.

On the frontier of technology, we have begun to explore AI applications in the context of digital heritage preservation. Particularly, the prospects of 3D Gaussian Splatting have shown promising results in initial tests, demonstrating improved levels of detail and visual fidelity. This cutting-edge technology offers exciting capabilities for future research and applications in the field of digital heritage preservation and engaging VR experiences in an artistic context. The role of narrative, performance, and music in fostering deeper emotional connections to heritage sites is an area ripe for further investigation.

In essence, the successful combination of these methodologies can offer a comprehensive, immersive, and emotionally engaging digital representation of significant cultural and natural heritage sites. By doing so, we can ensure their preservation and appreciation for future generations, creating a lasting digital legacy of our shared heritage.

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