REVISITING SHOEI YOH

Developing a workflow for a browser-based 3D model environment to create an immersive digital archive

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Abstract. The digitisation of architecturally significant buildings and sites creates opportunities to innovate methods of analysis, interpretation, representation, and audience engagement. To illustrate this potential, but also examine the attendant challenges, this paper outlines a research project that has digitised archival assets and living buildings designed by the Japanese architect Shoei Yoh to create an immersive 3D Spatial Archive. It focuses particularly on the creation of a browser-based 3D environment using WebGL technology that connects to and displays a repository of digitised archival assets. This includes the use of 3D scan data of Yoh's Naiju Community Centre project to accurately model the 3D immersive environment and a Grasshopper / Rhino into the glTF. File format (graphics library Transmission Format) workflow to render Naiju's complex geometry and detailed outdoor scenery. The paper demonstrates how using the .glTF File, which is an open format specifically for transmitting processed and pre-calculated 3D models, can improve the processing efficiency of web-browser based 3D environments. Improving the stability and processing speed of 3D browser-based environments is significant to enhancing how audiences can connect with and experience culturally significant sites remotely. The digital recreation and repurposing of Naiju (which is currently unoccupied and in a state of disrepair) as an immersive archival exhibition space operates to simultaneously protect the real building from over visitation, but also raise awareness of its cultural significance to support preservation efforts. In so doing, the paper makes a further contribution to the developing field of digital cultural heritage.

Keywords. Digital Cultural Heritage; Browser-based Modelling; glTF File, Architectural Visualisation; Shoei Yoh; SDG 9; SDG 11.

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1. Introduction

Digital cultural heritage is a field that seeks to creatively disrupt and transform heritage practices by engaging a range of digital technologies and techniques. An ecology of digital technologies offer new and sustainable ways to enhance the efficiency, accuracy, and scope of cultural heritage documentation (Yang & Greenop, 2020).

Within this field, much focus is given to the digitisation of architecturally significant buildings and sites through 3D spatial data capture (3D scanning). 3D laser scanning has generated opportunities to develop new methods to document and analyse culturally significant buildings and sites (Balzani, Maietti, & Kühl, 2017; Dong, Zhang, & Zhu, 2020; Uplekar Krusche, 2018). Equally, 3D scan data is useful for the virtual recreation of cultural sites (Aiello & Bolognesi, 2020; Zlot et al., 2014) and to guide physical restoration processes (Siu, 2021). The accuracy and detail of 3D scan data is also useful to processes of visual representation and the virtual (re)creation of significant buildings and sites as virtual 3D environments. Virtual recreations of lost and living buildings and sites equally facilitates new opportunities for analysis and interpretation but also new ways for global and intergenerational audiences to engage with and experience remote buildings and sites. The case example discussed in this paper involves the use of 3D scan data in a workflow to virtually recreate Japanese architect Shoei Yoh's pivotal Naiju Community Centre project in Fukuoka, Japan. This forms part of a larger and ongoing research project that has been digitising assets from Yoh's architectural office that were deposited with the Kyushu University, Fukuoka, Japan in 2019.

It has also involved 3D scanning Yoh's 'living' buildings. To both preserve and make these archival and new assets more widely accessible, the project team have created the online Shoei Yoh Archive that hosts both a traditional, searchable repository of digitised assets, but also a novel 3D 'spatial archive' which displays these multi-media assets in a more immersive and narrative-driven way. The development of the spatial archive as a browser-based 3D environment and its workflow that uses WebGL technology to address issues of stability and processing efficiency forms the focus of this paper. Accordingly, the following sections of the paper introduce the larger research project and its aims and detail the workflow components used to develop the spatial archive that include Grasshopper / Rhino into the glTF. File format (graphics library Transmission Format) to render Naiju's complex geometry and detailed outdoor scenery. The paper concludes by reflecting on the significance of 3D browser-based environments for enhancing how global and intergenerational audiences can connect with and experience archival materials as well as culturally significant sites remotely.

2. Research Project Background

The Japanese architect Shoei Yoh is an internationally recognised figure of late 20th century architecture and a pioneer of digital methods in architectural design (Lynn et al., 2013). In 2019 Yoh deposited his entire architectural office archive with the Kyushu University. Since then, a research team from the Kyushu University and University of New South Wales, Sydney, Australia have collaborated to digitise these archival assets, and 3D scan selected living buildings designed by Yoh. A core aim of the research has been to explore how to move beyond traditional searchable online repositories of archival material by creating a more compelling, narrative-based, contextualised, and immersive archival experience. To explore this the team proposed the idea of a spatialised archive as an environment to showcase the digitised assets of the Shoei Yoh Archive in a more relational way. The team chose to 3D scan and virtually recreate the Naiju Community Centre, which was completed in 1994 in the town of Chikuho, Fukuoka, Japan, but is now unoccupied and in a state of disrepair. In the context of the recent history of digital architecture, the Naiju community centre is considered significant as Yoh combined the use of locally grown bamboo, hand weaving construction techniques, and advanced computer analysis to realise a complex geometric form in bamboo and concrete. But this project was also chosen as the spatial archive environment as it connects to the larger story of Yoh's contribution to the modernisation of timber architecture in Japan through his engagement with digital technology, and namely early structural analysis software. Consequently, within the Naiju virtual spatial archive, archival assets, as well as new parametric models and 3D scan animations related to five other key projects designed and completed by Yoh between 1979 to 1994 are displayed. As such, the spatial archive is not simply a record or virtual recreation of Naiju but the vehicle through which its history and significance is interpreted and communicated. Moreover, as the spatial archive virtually reimagines and repurposes Naiju as an archival exhibition space, it combines the tradition of heritage preservation with a kind of digital futuring that aims to catalyse new thinking about the possibilities of its restoration and reuse.

3. Workflow development of a browser-based 3D virtual spatial archive

Representing architecturally significant sites in immersive and engaging ways has been aided by advances in tools such as 3D scanning along with falling costs in hardware, software, and data storage. But the dense data-capture of methods such as 3D scanning and point cloud models has equally bred a range of data management challenges. For example, practices of digital preservation that create digital records of existing sites can also be seen as fragile and precarious. As Greenop and Landorf argue, "*[c]onservation* in the digital era may not always involve preservation of the physical fabric itself, but *preservation* of a new, digital version of a heritage place" (Greenop & Landorf, 2017, p. 47). Equally, while the precision and scale of data that can now be readily accessed and used to virtually recreate highly detailed architectural heritage sites can also result in heavy models that can compromise audience experience and engagement through poor stability and low processing speeds. Developing a 3D browser-based environment workflow that addresses processing efficiency has been significant to realising the longer-term aims of this project which include extending the audience reach of the Shoei Yoh Archive and enhancing how people can experience culturally significant sites remotely.

3.1. BROWSER-BASED 3D MODELLING

To create the Naiju spatial archive the research team sought to leverage the possibilities of browser-based 3D modelling. The development of this work builds on prior research the team developed on web-browser-based 3D modelling and representation (Leung et.al, 2019). This includes pioneering work in 2018 on the use of JSON (Java Script Object Notation) and GeoJSON (3D extension of JSON) that is now the foundation of online modelling tools such as spacemaker.ai; giraffe.build; and/or testfit.io.

JSON (2021) is a lightweight data-interchange format. It is easy for humans to read and write. It is easy for machines to parse and generate. It is based on a subset of the JavaScript Programming Language Standard ECMA-262 3rd Edition - December 1999. JSON is a text format that is completely language independent but uses conventions that are familiar to programmers of the C-family of languages, including C, C++, C#, Java, JavaScript, Perl, Python, and many others. These properties make JSON an ideal data-interchange language. Ibid. continues by explaining that JSON is built on two structures:

- A collection of name/value pairs. In various languages, this is realized as an object, record, struct, dictionary, hash table, keyed list, or associative array.
- An ordered list of values. In most languages, this is realized as an array, vector, list, or sequence.

As these are universal data structures virtually all modern programming languages support them in one form or another. Consequently, it makes sense, according to Ibid. that a data format that is interchangeable with programming languages also be based on these structures.

GeoJSON on the other hand is a format for encoding a variety of geographic data structures (GeoJSON, 2021). In 2015, the Internet Engineering Task Force (IETF), in conjunction with the original specification authors, formed a GeoJSON workgroup to standardize GeoJSON. The Request for Comments (RFC) 7946 was published in August 2016 and consequently GeoJSON is the new standard specification of the GeoJSON format, replacing the 2008 GeoJSON specification. GeoJSON supports the following geometry types: 'Point', 'LineString', 'Polygon', 'MultiPoint', 'MultiLineString', and 'MultiPolygon'. Geometric objects with additional properties are 'Feature' objects. Sets of features are contained by 'FeatureCollection' objects. (Ibid.)

While JSON is now commonly used for transmitting data in web applications the use of *.obj or *.fbx formats offer only a slow experience in particular when transmit a 3D scene data efficiently over the internet for viewing in a remote application. Thus, this research used Shoei Yoh's Naiju project with its complex geometry and its detailed outdoor scenery as an example to develop a workflow from Grasshopper / Rhino into the glTF. File format (graphics library Transmission Format).

According to Wikipedia's entry on glTF (2021) it is a standard file format for three-dimensional scenes and models. A glTF file uses one of two possible extensions, *.gltf (JSON/ASCII) or *.glb (binary). A *.glTF file may be self-contained or may reference external binary and texture resources, while a *.glb file is entirely self-contained. It is an open standard developed and maintained by the Khronos Group, an open, non-profit, member driven consortium of 170 organisations developing, publishing and maintaining royalty-free interoperability standards for 3D graphics, virtual reality, augmented reality, parallel computation, vision acceleration and machine learning. A *.glTF file supports 3D model geometry, appearance, scene graph hierarchy, and animation. It is intended to be a streamlined, interoperable format for the delivery of

3D assets, while minimizing file size and runtime processing by apps. As such, its creators, lov.gov (2021) have described it as the *"JPEG of 3D."*

Thus, as a *.glTF File format is an open format specifically for transmitting processed and pre-calculated 3D models it has the potential to become the solution to the problem of the proliferation of proprietary, closed, and restrictive cloud 3D viewing formats - an interest that the development of the Shoei Yoh Archive aimed to investigate. This notion is based on the observation that a *.glTF is more suitable for viewing models than editing them - a *.glTF has no parametric features, or blocks, or arrays, or any other complex geometry forms. Given this it was deemed a more suitable approach for digital cultural heritage projects.

3.2. SET UP AND METHODOLOGY FOR DEVELOPMENT

In agreement with our web developer partner Special Design Research Studio, Sydney we proposed a scrum / agile methodology with a series of four sprints for the software development and action research methodology for collaborative researching the topic with our web developer partner. We started Sprint 1 in early May 2021, but at this time we had little processed digital data of Naiju to work with. Our team has been on site at Naiju in Japan in February 2020 and had taken photos as well as preliminary 3D scanning of the Naiju exterior with a LeicaBLK360 3D scanner. At this point the Naiju plans, sections, elevations, or detail drawings had not been digitised.

Sprint 1 - 3D modelling a first trial. As such, the development work began with a trial using a simplified 3D model generated in Unity, shown in Figure 1. This allowed us to explore the opportunities, constraints, and limits of bringing a 3D model in a web environment.

Figure 1. 3D model first iteration in Unity (left), Naiju Community Centre photographed during site visit in February 2020 (right).

The trial 3D model was examined according to key categories including topology, UV maps, pivot points and other potential artefacts along with some well-crafted attributes. The following errors were identified and required.

- **Pivot Points.** The pivot point was set to the far left to the following 3D coordinates: X 21765.302 / Y 16559.705 / Z 329.404. It was agreed to readjust the pivot point to be in the centre of the model and have the pivot placed in the accurate base position.
- **Topology.** Given the structure and shape of the 3D model, the shape does not capture the exact silhouette of the Naiju model from the external view. There are

multiple sections of the model that present some odd polygons and triangles. These are topology issue that will cause some artefacts and shadow artefacts in Unity. Furthermore, the model had numerous stretched polygons on the neck of the top section of the model and multiple jagged vertices and edges jutting into the inner creases of the model. It was agreed to clean these out to void any blur/unclean shadow lines. The results from these were also show internal as polygons were pushing inside the exhibition space, showing bad artefacts.

- **UV Map.** The overall UV (The letters "U" and "V" denote the axes of the 2D texture because "X", "Y", and "Z" are already used to denote the axes of the 3D object in model space, while "W" (in addition to XYZ) is used in calculating quaternion rotations, a common operation in computer graphics) maps have been created neatly for the most part, however there were signs of overlapping UV maps. It is important to keep these flat so that light baking and texture work is accurate and there is less chance of stretching. In addition to this there was a lot of empty space, which could be used better by scaling the UV maps/or by including more topological data.
- **Materials IDs.** It was agreed to consider assigning UV IDs for model interior and exterior and to scale each UV island to use up all the space within the UV layout.
- **Open Geometry.** The edges of the building were not enclosed and left open, resulting in the model showing paper thin like borders which can cause shadowing issues as well as limiting the use of isolating the 3D object as it is not a solid 3D object.
- **Texture work.** Texture work on the exterior environment showed a promising start. However, it was noticed to keep in mind of the scale of the environment in relation to the tile able settings on each material. For instance, if the structure is meant to be large in scale, the camera will be all the way close to the model which would show the blurry large textures if not scaled accurately. Due to the poor UV mapping, the textures on the internal dome were also very pixelated and poorly presented.

At the completion of Sprint 1, it was agreed to minimize and eliminate the risk of technical issues mindful of the following additional findings:

Firstly, do not use any third-party assets or applications which are primarily not built for WebGL, such as Gaia, this most likely has been the cause of the file size exceeding 4.5GB.

Secondly, we will export all 3D models as *.FBX and not *.OBJ as this will help in keeping files more readable within Unity.

Thirdly, to keep all texture images to the power of 2 e.g., 512x512, 256 x256 in width and height.

Fourth and lastly, to name all objects in your scene appropriately, as these will be called out via code in the future for optimization needs.

Sprint 2 - Unity Package Check. With the feedback of Sprint 1 and having gained access to digitised plans, sections, elevations as well as processed 3D scan data of Naiju in mid-June 2021 we were able to produce base model geometry correctly using GH / Rhino 3D. Yet problems occurred in the polycount of the model. Here the model, excluding landscape/environment, had a total of 12,621,597 polygons and 6,311,534 vertices. This created problems with rendering on a web browser. It was agreed to optimize the model within 40K to 50K polygons maximum and keep the shape intact.

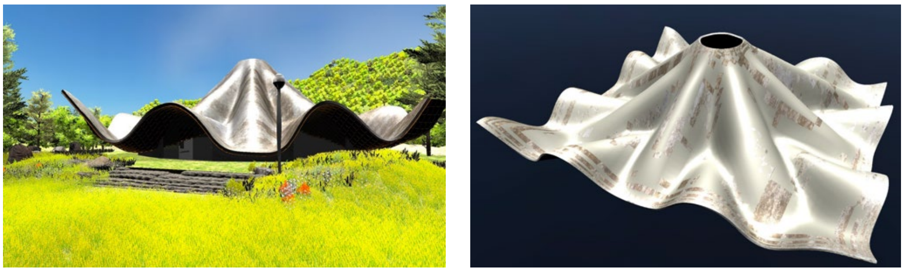

Figure 2. 3D model second iteration in Unity (left), broken model due to OBJ export (right).

This was based on research and experience that demonstrated that anything larger can cause significant lag and overly complex UV maps. If a lower polygon count could not be achieved, the alternate consideration was to create various LODs (Level of Details) in the model as this would allow the camera to render based on distance. Following corrections were identified and required in sprint 2.

- **FBX export.** Model was not exported as native 3D software *.FBX but *.OBJ. Due to this, the UV maps were inaccessible and showcasing inaccurate UV maps/seamlines which seem very broken and inefficient as there were multiple broken seam lines visible. While this was an oversight of an action item (see above) in Sprint 1 it demonstrated the importance to use the *.FBX format.
- **Pivot Point.** Again, a problem raised in Sprint 1 but overlooked as now several models were placed into the environment.
- **Naming convention.** Most models were named correctly, however, not all objects were named correctly. There are a many that still are labelled as Object_#. Causing issues.
- **Interior Mesh Gaps.** Model placement for the interior space had gaps, especially the floors. As we intended that the user will be able to walk and look all around, it was important to address these issues as one will easily see the gaps between each level.
- **Backed Lightmaps.** At this Sprint 2 the question of lightmaps were discussed for the first time. It was agreed that once the topology/segments were reduced, it would be beneficial to add lights in the 3D software of choice and bake the lighting information onto the UV maps of the model and export the data out as texture maps. This then can be then implemented into Unity and reduce the usage of Directional/spotlights in Unity.

To summarise Sprint 2. In moving forward, once aspects of the main structure were fixed, it was proposed that all vegetation and painted grass on the terrain be removed, and the terrain was converted into a mesh (See Figure 2). This was based on knowledge that Unity, and most game engines, typically become overly heavy when terrains and 'SpeedTrees' are used. SpeedTree is a 3D vegetation modelling and middleware used to create trees and plants for films and television. For a web browser application these are not suitable and were replaced by static panoramic spheres with images of trees to incapsulate the vegetation in the following.

Sprint 3 - Clean up model and set up of environment with lights. In this third sprint from June to end of July 2021 the model required several aesthetic changes to meet the expectations of the team towards a near photorealistic experience on the browser. The model contained multiple vegetation assets which needed to be removed and light sources in the scene were deleted. And, while the topology on the model was already reduced to approximately 100k polygons, further reduction was required. In this sprint 3 following corrections were identified and required:

Figure 3. Third iteration now on the web browser exterior view, and first interior views.

- **Vegetation.** We deleted 70% of vegetation for optimization purposes.
- **Illumination**. Lights baked and positioned in areas required.
- **Size of model.** Topology was reduced to 21k polygons, texture work and materials created to compliment lights.

While the results started to look promising it was agreed to work on further refinements in terms of optimization weight, lighting/saturation, etc.

Sprint 4 - Interior and adding interior assets such a photo, video, sounds, and 3D model. In the fourth and final sprint, the static media content was integrated within the model. The photos and videos were split into folders with each path for the folders aligned to a display panel inside the gallery space. This integration was developed to allow the referencing link to each file within the folders to remain the same, which meant that the content was able to be changed provided the naming convention for the new files matched the referencing links in the model. For the deployment of the 3D parametric models on the plinths inside the Naiju exhibition space, each 3D model needed to be baked into the Unity model. This process of integration needed the 3D models to be further optimised by reducing the polygon count. This optimisation process was achieved by only utilising one face of each truss structure and keeping all faces as quad polygons. With the media referencing and 3D model optimisation completed, the model needed to be transferred from its local server to an online storage and display solution. Amazon Web Services (AWS) was used to facilitate this process as its services allowed for a fast transfer speed at a global scale. The Unity model itself also needed to be integrated onto a webpage for users to access the model on a browser. With this objective, the entire website was developed with HTML, CSS, and JS. All the webpages and media content were deployed onto a public AWS S3 bucket. Using AWS Cloudfront, a distribution service was setup for the S3 bucket which allowed the entire website and Unity model to be cached on local distribution servers in each country, allowing users to access the data from their devices at the fastest speed available. Finally, using AWS Route53, the name servers for the hosting URL were pointed towards the Cloudfront distribution servers which completed the online hosting and integration process. With all sprints completed the project went live at 8pm on 2nd December 2021 and can now be accessed at https://shoeiyoh.com/.

Figure 4. Naiju Community Centre on the Shoei Yoh Archive.

4. Conclusion

The digitisation of architecturally significant buildings and sites creates opportunities to innovate methods of analysis, interpretation, and representation, but also extend audience reach and engagement. The falling cost of 3D laser scanning equipment and data storage, along with the use of technologies such as drones and sensors make the collection of data about living buildings and sites far more accessible and continual. But the high precision and granular nature of this data, while useful for a range of analytical and interpretive purposes, brings forth attendant issues of data handling and management. In the context of virtual recreations designed for online public outreach, the richness of data can work against the goal of creating accessible, high quality and immersive modes of remote audience engagement. To explore these issues, this paper has drawn on the case example of virtually recreating Japanese architect Shoei Yoh's pivotal Naiju Community Centre as a novel browser-based 3D spatial archive. It has shown that a browser-based 3D model environment and data management methods adopted are a suitable to the virtual recreation of significant buildings and sites for the purposes of public engagement in digital cultural heritage projects.

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