

# Experiencing Heritage through Immersive Environment using Affordable Virtual Reality Setup

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## ABSTRACT

Virtual reality (VR) technology allows the reproduction of spatial experience in a digital environment and simulates both real and imaginary world experience. The experience is created for various devices with different degrees of immersion. Several use cases of VR utilization have been explored in the architectural field, including historical buildings exploration in a distant place. However, VR is often associated with high investment in hardware and software. This study demonstrates VR utilization to experience off-site exploration of architectural heritage using a low-cost hardware setup and open-source software. We propose the possible workflow to create VR assets using Blender. Furthermore, we investigate the authoring pipeline to optimize the model for various devices. The result will be deployed as a VR environment under Mozilla Hubs, a WebXR-based platform that users can access simply from a web browser. With this workflow, the goal is to provide a low-cost VR experience for everyone where the environment can be easily accessed using the available existing device.

**Keywords:** Virtual reality, Architectural heritage, WebXR, Low-cost VR.

## 1. INTRODUCTION

Virtual reality gains popularity for its ability to transmit places into our current spatial reality as it was predicted by Negroponte [1], '...transmission of place itself will start to become possible'. It changes the way we perceive space as geographically limited entities. It is made possible through three properties of virtual reality: 1) interactivity, 2) immersion, and 3) imagination [2]. Users can interact and modify the object in virtual reality instantaneously, which allows them to immerse in the experience as it involves their sensorial modalities. Our mind's capacity to understand the abstraction of the simulated realities also helps to perceive the world as existing. Hence we believe that our presence is teleported to another place [3].

VR offers the benefits of a higher immersion degree for users. It provides better spatial relationship understanding, improved interaction, and reduced information clutter [4]. The use cases include remote site exploration [5-7], language acquisition [8], reduced training cost [9], promotion of cultural heritage [6,10] and retail consumer's experience [11]. VR also retains attention through interactive objects and an immersed environment; and triggers the viewer's imagination [12]

in games, simulation, and virtual worlds, which are practical content delivery tools [13]. VR helps users experience natural settings [14] bringing the sense of presence to optimize the experience inside the simulated reality [15].

However, VR still fails to gain widespread adoption despite its numerous positive findings [16]. Initial costs remain high, including hardware setup, software purchase, and technical support [17,18]. Even the mention of low-cost VR adoption still requires a desktop PC with a high-end graphics processing unit [19,20] and is often strongly associated with HMD devices [21]. Barriers to VR adoption include lack of interoperability and a limited number of participating users [18,22].

In this research, we propose a low-cost VR creation workflow model that addresses hardware and interoperability issues. First, we address the point that people should understand VR in a broader definition to tackle its technical limitation. Further, we use open-source software to reduce costs in all stages of VR environment development, from creation to deployment. We will also demonstrate how people can use WebXR technology to increase interoperability between different

platforms and promote a collaborative VR environment. This study aims to introduce an affordable VR authoring pipeline that people can use to promote the architectural heritage experience.

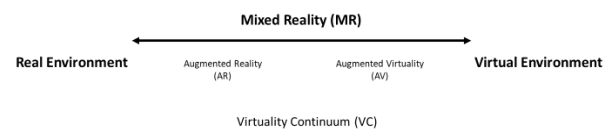
## 2. DEFINING VIRTUAL REALITY

Virtual reality (VR) has loose definitions. The first definition can be referred to as a *computer-generated digital environment that can be experienced and interacted with as if that environment were real* [23]. The computer-generated sensory experience allows the user to feel present in the simulated environment. This definition is broad, with a wide spectrum of devices that can replicate the virtual reality experience and interaction in different levels of Immersion. The second definition has a stricter criterion. Virtual reality can also be defined as *cutting-edge sensory immersive technologies that use head-mounted displays and an elaborate array of body sensors to enhance, elaborate, and expand our sensory interaction with new media objects* [24]. Users need wearable devices to simulate sensory experience as they interact with the things inside the virtual environment. Head-mounted displays (HMD) provide visual sensory complemented with other devices to provide acoustic and haptic feedback. Between the two definitions, the first definition is more accurate to represent virtual reality in current practice [2].

Burdea and Coiffet [2] described that VR has three properties of I's:

1. Interactivity, where users interact with the object on the screen in real-time, allows them to modify the virtual world instantaneously.
2. Immersion as modification of the virtual world involves sensorial modalities that make the experience captivating. Hence, users immerse themselves in the virtual world.
3. Imagination, which is related to our mind's capacity to perceive the simulated realities inside the virtual world as existing.

Virtual Reality (VR) needs to be distinguished from Augmented Reality (AR). While most of what users see is still a real world in AR, users are fully immersed in a virtually-created environment in VR [25]. The distinction between the two is best explained through the Reality-Virtuality (RV) Continuum by Milgram and Kishino [3] (Figure 1).



**Figure 1** Virtuality Continuum (VC) adapted from [3]. Note that virtual reality was mentioned as Augmented Virtuality (AV).

	Non-immersive		Low Immersion		High Immersion		
	Desktop Devices		Wearable Devices		External Devices		
<b>Visual</b>	Monitor	Workbench	HMD	Retinal Display	Powerwall	Panoramic Powerwall	CAVE
<b>Acoustics</b>	Desktop Speakers		Headphones			Multichannel Speakers	
<b>Haptics</b>	Desktop Haptics		Wearable Haptics		Encountered Haptics		Real Objects
<b>Motion</b>			Whole Body Motion Interface			Motion Platform	

**Figure 2** The degree of Immersion redrawn from [26].

Virtual reality has various degrees of Immersion [26]. It ranges from non-immersive to high Immersion with multiple devices that offer a multitude of sensory feedback (Figure 2). Any device with a monitor display in the lower immersion spectrum could be included as a virtual reality device. In the middle range, wearable devices such as HMD and retinal display provide a higher degree of Immersion by isolating the vision of its user from their surroundings. At the highest end of the immersion, spectrum is CAVE and Powerwall. The virtual environment is externalized in these devices, which provides users with natural interaction on a 1-to-1 human scale.

### 2.1. Virtual Reality in Architectural Heritage Case Studies

In architectural heritage case studies, VR is helpful to inform the public about the importance of heritage buildings by providing deeper engagement and informed interpretation of the buildings [27-29]. It is demonstrated through the case study of Gordon Wilson Flats in New Zealand, an essential modern architectural heritage that was perceived negatively and overlooked by the public. Despite being remarkably significant for the history of contemporary building technology in New Zealand, its significance was obscured by the

deteriorating condition [27]. The study demonstrates that VR can help the public to experience the dynamic nature of the building throughout its lifecycle. Where access to the heritage building is not available, VR allows the public to experience the building first-hand through an interactive virtual environment. VR also facilitates communication by presenting public the architectural significance of the building in its tangible and intangible qualities [28].

While authenticity is often questioned when architectural heritage buildings are turned digital, it can be argued that the goal of digitalizing the heritage building is not to preserve physical authenticity. Frequently, the goal is to enhance the interpretation of heritage buildings through a certain degree of abstraction [30]. The artistic approach might be used to engage with the observers inside the virtual environment to contextualize the heritage in multiple chronological states to enrich the experience. A creative process is used to improve the communication of the value of both tangible and intangible heritage rather than to resemble the physical entities of the building that is limited to prescribed interpretation and definition. Thus, VR facilitates the public to adopt multiple variations through enhanced information.

VR is also captivating that makes the public well informed about the significance of the heritage buildings. VR technology has been proven to outperform printed media and web pages in disseminating historical information because it is more enjoyable and motivating [5].

## **2.2. Virtual Reality Authoring Workflows**

Most virtual reality researches in architecture are in the stage of prototyping [31]. Various prototypes use different authoring workflows to produce virtual reality. It involves different methodologies for capturing and disseminating the virtual reality experience. There are three commonly used workflows for authoring found in previous researches:

1. In the first workflow, the data is captured by using a 360-degree camera in the location of the building. The disseminated results are spherical images or videos that represent the actual situation of the building [5].
2. In the second workflow, the data is obtained from archives and measurements in the field. The building is later reconstructed digitally as a three-dimensional model to represent the physical form of the structure accurately. The results are then disseminated as stereoscopic pre-rendered equirectangular images to provide the immersive experience of being inside the virtual environment [6]. Using pre-rendered images allows reducing computing resources to experience virtual reality.

3. The third workflow involves reconstructing a three-dimensional virtual environment using a laser to capture point cloud data. Next, the data will be extracted and modified to visualize the geometry [32]. The goal is to create the closest representation and accurate model of the building.

In the first and third workflow, special equipment is needed. The first workflow requires a 360-degree camera to capture images and videos across 360 degrees. It enables to capture the surrounding environment without stitching individual images to produce immersive spherical photos and videos. The third workflow uses laser scanners to capture the point cloud. Although the results can produce accurate geometries of the digital building model, the high initial cost is the drawback of the technology. The second workflow does not require special equipment. It also allows the results to be viewed using a low-cost head-mounted device (HMD) like Google Cardboard because the images are pre-rendered to save computing resources. The images are rendered as an equirectangular images to allow for immersive viewing.

## **3. METHODOLOGY**

To explore the low-cost VR creation workflow for heritage experience, we use an architectural heritage building of "Istana Peraduan", located in Siak Regency, Indonesia. To build the 3D model for our study, we acquired detailed measurements and photographs of the building. The data was provided by the architectural conservation team from the Siak Regency.

The purpose of this research is exploratory that allows the researchers to develop the theory. The structure follows a linear-analytic format [33]. Researchers define the problems and pose research questions, conduct a literature review, describing its methods, and present the findings and conclusion at the end. The literature review is conducted to provide analytical tools for the exploratory study. The analysis employs qualitative strategies to explore the workflow of VR creation.

To explore the workflow from start to finish, we use "Istana Peraduan" at Siak Regency, Indonesia, as our case study. The building was the private residence of the Siak Sultanate that was constructed in 1915 to 1916. The architecture itself combines neoclassic and local Malay architectural style. While it boasts handcrafted European door locks and hinges, the building geometry is relatively simple. The building is well preserved and still features many of its original architecture. It has historical significances for the Malay community in Siak because it was the private residence for the last sultanate of Siak before the throne was given to the newly found Indonesian republic (Figure 3).



**Figure 3** The current condition of Istana Peraduan at Siak that become our case study (Source: Siak Heritage Conservation Team).

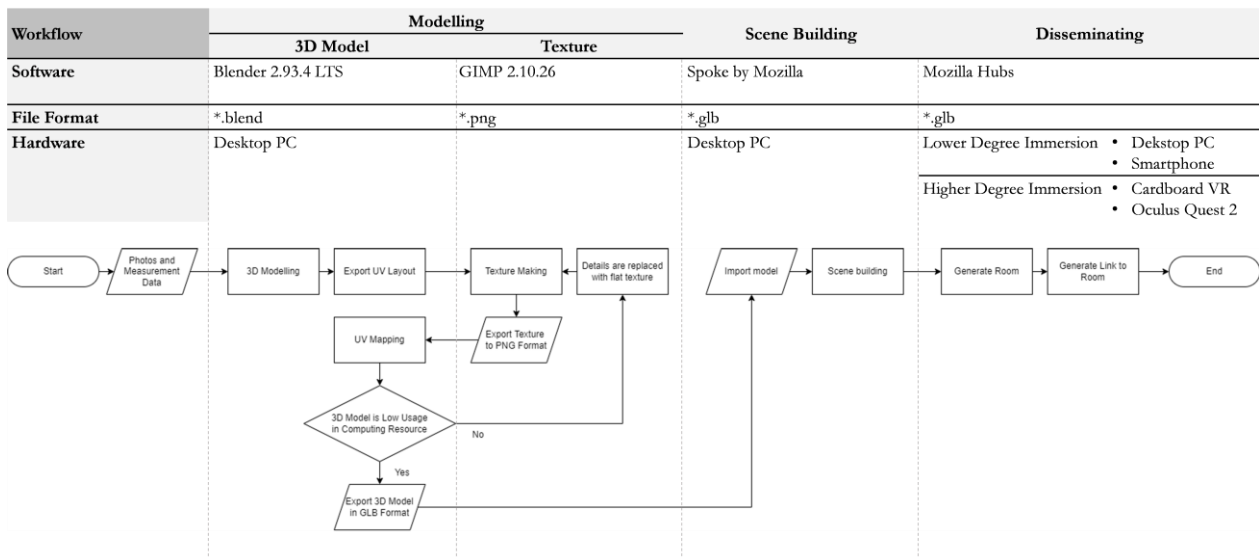
Before we start the modelling process, we collected data of the building measurement. Although we were remote from the location of the case study, we were glad to be able to collaborate with the heritage conservation team in Siak Regency. The team kindly provided us with detailed measurement of the building, photographs of the building, historical archives, and close-up of the architectural details. We communicated remotely by teleconferencing to show our progress and receive feedbacks.

## 4. IDENTIFYING THE WORKFLOW OF VR CREATION

Our workflow of VR creation is targeted for multiple devices. So, we have to create VR experience that can be viewed in many devices across various immersion degree. We targeted non-immersive to low-immersion viewing devices, which include monitor-based devices (desktop PC and smartphones) to standalone and PC-based VR devices. The workflow of VR creation can be divided into three stages:

1. Modelling
2. Scene building
3. Displaying

Our approach involves the use of Free and Open Source Software (FOSS) across all stages of development (Figure 4). The software that we use are Blender 2.93.1, Inkscape, Spoke, and Mozilla Hubs. We chose FOSS to demonstrate that virtual reality experience does not necessarily require proprietary and paid solutions. We also use Mozilla Hubs because it utilized WebXR technology, which does not require installment from the client-side and provides a collaborative multi-user virtual environment.



**Figure 4** The flowchart demonstrates virtual reality authoring workflow using Free and Open Source Software (FOSS).

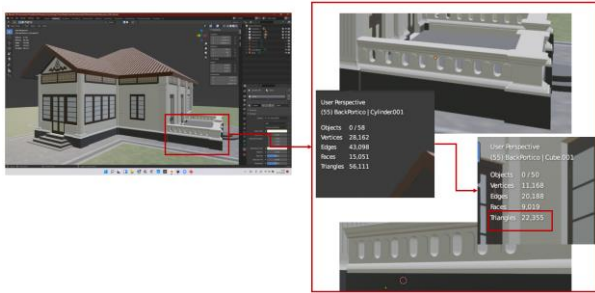
### 4.1. Modelling

To optimize the model, we identified the basic geometries, salient architectural features, and architectural details. We aimed to reduce the number of triangles to increase the computing performance. During the modeling process, we turn on statistics to keep on the number of triangles of the building geometry. The

3D model was built using Blender modeling and modifier tools.

We realize that extensive architectural details such as recess in the column body and decorative elements on the façade could result in high number of triangles. While it was necessary to keep the architecture as detailed as possible, we had to consider the limited computing resources to avoid poor performance on the

VR devices. Thus, extensive details were replaced with flat textures (Figure 5). We managed to significantly reduce the number of triangles and improve the 3D model performance for web view.



**Figure 5** Optimization of the 3D model for web viewing by replacing geometries with flat textures.

The image texture was created by exporting the UV layout of the 3D model editable SVG format. The SVG files were imported into Inkscape, an open-source vector-based image editing program. Inside Inkscape, architectural details were drawn by retracing the outline of the parties. To add a sense of depth that was lost in two-dimensional image texture, we added shadow effect to create depth illusion. The finished result was then exported as a PNG image. In Blender, the exported PNG image was mapped onto the UV layout.

After the 3D model was finished, we exported the file into GLB format, which is the standard format for web 3D models. Blender supports export to GLB format natively that streamline the exporting process.

## 4.2. Scene Building

Next step is called "scene building". The purpose of this step was to import 3D model into the virtual environment that allowed the model to be accessible for viewing. We used "Spoke by Mozilla Hubs" that runs as a WebXR-powered virtual environment editor. The GLB model was imported into Spoke. Then, we changed the coordinates through the graphical user interface (GUI) menu to set the location of the 3D model on the cartesian plane. Further, we set the spawn point for the observers so they face the front façade of the building when they enter the virtual reality. Next, we added images and texts to enrich the information about the building. After we finished building the scene, we publish the scene to Mozilla Hubs. Publishing the scene allowed us to generate room for the public to enter and experience the scene.

## 4.3. Disseminating

The last step is to disseminate the virtual reality experience on the web. To provide the shared experience, we have to generate "Room". We started by creating room and changing the default scene into our

published scene. Then, we can generate invitation link so other people can join the room. The generated URL can be inserted into a web browser to access the room. Since Mozilla Hubs use WebXR technology, it works on any modern browser. It is cross-compatible with many devices, including smartphones, desktops, and HMD VR devices. It also does not require users to install the additional dedicated application because they can be accessed using a web browser. However, Mozilla Hubs warned that the optimum number of people joining the room in a session is limited to 25 people to reduce performance issues.

## 4.4. FOSS Workflow

The availability of Free and Open Source Software (FOSS) helps to reduce software costs. As demonstrated in our workflow, FOSS is available in every stage. So, it is possible to generate virtual reality content from making to disseminating using freely available software. We also demonstrated WebVR technology in the last stage of our workflow. It allows the content to be distributed to various platforms without a dedicated application. Virtual reality can be experienced by simply visiting the link using any modern web browser. It reduces the barrier by providing easy access to virtual reality.

However, we noted that Mozilla Hubs was developed as a collaborative social web application. The scene-building tools were limited. We noticed that creating a "hotspot" or interactive menu inside the virtual reality was not possible. While users could interact and engage with other users because of its social function, the server was only capable of handling 25 people inside the room in a session. There are performance issues that make the experience less optimized for virtual reality.

## 5. CONCLUSION

Virtual reality helps people engage with the content in an immersive and interactive environment. Hence, the users believe that they are transported to another place. The sense of presence has been proven to outperform traditional media to disseminate information. However, barriers to adoption prevent people from creating and experiencing virtual reality. It includes high initial cost and technical issues of interoperability.

We started by defining virtual reality in broader terms. We showed that virtual reality definition should not be confined to the use of dedicated head-mounted devices (HMD). Instead, virtual reality experience should be able to be enjoyed from various devices within a different spectrum of immersion degrees. We also decided to use free and open-source software (FOSS) to demonstrate that the virtual reality authoring process did not require a high cost to purchase the

software. These two approaches can tackle the issue of increased initial price by providing various options for creating and disseminating virtual reality experiences.

We demonstrated that FOSS could be used in various stages of the virtual reality authoring process. However, we still notice performance issues and limited tools to build more interactive and engaging content. Further, WebXR technology can be utilized to reduce the barrier by providing multiple platform experiences. WebXR allows virtual reality content to be disseminated using a web browser that can be accessed from various devices.

Future exploration on the use of FOSS in the virtual reality authoring process could reduce barrier adoption to the technology. Further, we encouraged future studies on the WebXR technology, which allows virtual reality content to be quickly disseminated to the public. If virtual reality experience is widely accessible for people, then people might widely adopted virtual reality to enrich the experience of architectural heritage.

After the 3D model was finished, we exported the file into GLB format, which is the standard format for web 3D models. Blender supports export to GLB format natively that streamline the exporting process.

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