**Engineering and Technology Journal e-ISSN: 2456-3358**
**Volume 09 Issue 11 November-2024, Page No.- 5463-5468**
**DOI: 10.47191/etj/v9i11.01, I.F. – 8.227**


# Application of WebVR Technology for 360-Panoramic Heritage Exploration: A Case Study of Wat Phou Heritage, Laos

**Vatthana Vongpaxa**
Thu Dau Mot University, Binh Duong Province, Vietnam

**ABSTRACT:** Virtual tours serve as powerful tools for education, preservation, and accessibility, especially within cultural heritage. This study develops a web application that utilises 360-panoramic views to elevate user experience in tourism promotion. Current digital tools for cultural sites often rely on static text and images, limiting the depth of user interaction. By integrating 360-panoramic technology, this project addresses these limitations, offering a more immersive and engaging experience. Focusing on the Wat Phou monument in Laos, the study utilises the open-source WebVR PannellumJS framework and advanced equipment, such as 360-degree cameras and UAVs, to create a lifelike and interactive exploration of the site. Panoramic images are linked to simulate a tour route, and traditional "hotspot" nodes guide users through a virtual experience with navigation options and full-screen viewing for orientation support. This research underscores the potential of VR360 technology in enhancing tourism promotion and heritage digitisation, ultimately fostering visitor engagement and contributing to socio-economic development through innovative cultural experiences.

**KEYWORDS:** VR360 virtual reality technology, PannellumJS, 360-panoramic, Wat Phou, Cultural heritage.

## I. INTRODUCTION

In recent decades, the dynamic and competitive landscape of tourism and cultural heritage management has prompted these sectors to integrate information and communication technologies to enhance visitor experiences (Tussyadiah et al., 2017; Fan et al., 2024). This technological suite includes interactive websites, social media, smartphones, tablets, computers, and mobile applications (Li et al., 2024; Wieland et al., 2024), with augmented reality (AR) and virtual reality (VR) applications gaining particular attention (Han et al., 2017; Trunfio et al., 2021). In cultural heritage tourism, institutions such as museums, archaeological sites, and galleries increasingly explore these tools to deepen the visitor experience before, during, and after visits, reflecting a broader market-oriented approach (Abernathy et al., 2018; Errichiello & Micera, 2018). The VR can be defined as “the use of a computer-generated 3D environment (e.g., ‘virtual environment’) that one can navigate and possibly interact with, resulting in real-time simulation of one or more of the user's five senses” (Guttentag, 2010, p. 638). Unlike AR, which layers digital information over the real world, VR fully immerses users within a digitally created environment (Yung, R. et al., 2017). Over recent decades, research has increasingly recognized VR as a powerful tool for promoting tourism destinations and cultural heritage sites, as it enables a heightened level of interaction and engagement for prospective visitors (Huang et al., 2013, Jung, T., 2017). This application of VR enriches the visitor experience by providing a more comprehensive, immersive, and interactive exploration of cultural and informational content, which enhances its role as a dynamic marketing and engagement platform.

The COVID-19 pandemic further accelerated the adoption of virtual experiences, including 360-degree VR tours, as a way to address restrictions on travel and in-person events (Sarkady et al., 2021; Rahim et al., 2020). During this period, 360-degree panoramas gained prominence, offering immersive and interactive experiences not only in cultural heritage and tourism (Mohammad & Ismail, 2009) but also in areas such as real-estate visualization (Pleyers & Poncin, 2020). These technologies are now seen as valuable tools for engaging audiences remotely, indicating a shift toward digital experiences that continue to enhance visitor engagement in tourism and heritage sectors.

In the era of the Fourth Industrial Revolution and digital transformation, VR360 technology has emerged as an essential and transformative tool across multiple sectors. As a sophisticated technological innovation, virtual reality has redefined how users experience and engage with digital environments (Lin et al., 2024). Through advanced computer graphics, motion sensors, and immersive display systems, VR360 enables users to interact with highly realistic simulations of both actual and imagined settings. This technology has demonstrated significant value in various fields, including gaming, education, healthcare, real estate, and beyond (Rojas-Sánchez et al., 2022).

Research on 360-degree panorama tours in heritage interpretation highlights their potential to enrich visitor

engagement and educational experiences. Studies, such as El-Said et al. (2021) and Shadiev et al. (2022), confirm the effectiveness of these tours in enhancing learning and satisfaction. Additional research has explored the tools used to create these tours, assessing their accuracy and information quality (Gafar et al., 2022; Barkatov et al., 2020). Despite the proven benefits, few studies focus on optimising workflows for creating interactive 360-degree tours for historical sites or systematically integrating multimedia elements like audio and 3D models, indicating a gap in research on user experience and tour functionality.

Research on 360-degree panorama tours has extensively explored technical elements, such as camera systems (Amezquita, 2022) and free stitching software for high-quality panoramas (See et al., 2019), along with design and user interface impacts on tour effectiveness (Kim et al., 2018). However, despite their popularity, studies comparing the features of 360-degree tour-making software and detailing development workflows are limited, especially regarding integration of interpretative content for a deeper user experience.

The Vat Phou complex, a UNESCO World Heritage site since 2001, is in Champasak Province, Laos, along the Mekong River. This ancient temple complex, built by the Khmer Empire from the 11th to 13th centuries, is situated on the sacred Liṅgaparvata, or "Liṅga Mountain," which symbolised Hindu beliefs. Noted for its architectural evolution from the 5th century, the site reflects significant cultural and religious heritage, intertwining Laotian and Khmer legacies.

This paper addresses the heritage sector's use of 360-panorama tours, an immersive technology allowing users to explore virtual environments through interconnected 360-degree images enhanced with interactive hotspots and multimedia annotations. Initially, it provides a comparative analysis of popular software and services for creating these tours, followed by a detailed workflow for developing an interactive 360-panorama tour, showcased through the heritage site Wat Phou in Laos.

Aiming to create an engaging and authentic experience to attract tourists and communicate the cultural significance of Wat Phou, this research proposes an advanced technological solution using VR360 for heritage tourism. The study introduces a model that combines cultural preservation with tourism development through VR technology at Wat Phou, assessing its effectiveness in engaging tourists and enhancing heritage communication. This research contributes to tourism development while promoting digital transformation and innovation in marketing and heritage communication, leveraging VR360's potential to deliver an interactive, immersive experience that appeals to market demands and broadens accessibility for tourism projects.

## II. METHODOLOGY

The 360-panorama heritage tour technology offers promising potential for immersive experiences, yet requires critical assessment of accessibility, innovation, and collaboration to fully realise its impact. The VR360 virtual reality model was developed using the following methods:

***Photography Design Method:*** This was used to select strategic photography locations that highlight the historical and cultural value of Wat Phou in Laos.

***Digital Image Processing Method:*** Applied to fine-tune image parameters after fieldwork, focusing on editing effects, integrating 360-panorama, and post-processing tasks like object removal. Various algorithms were utilised to handle aerial images from UAVs and ground-based shots, using software like Adobe Photoshop, Adobe Lightroom, and PTGui to create seamless panoramic visuals.

***Implications VRTour:*** Panoramic images were stitched together and modeled to form a virtual space mirroring the actual environment, created on the open-source WebVR PannellumJS framework. Information features such as navigation buttons, images, videos, and text documents were incorporated into the virtual model. The VR model was designed for desktop and mobile versions to ensure compatibility across various devices, enhancing accessibility.

The spherical panorama rendering can be used for interactive display on digital platforms, commonly known as the VR360 experience. This allows users to explore the 360-panoramic scene interactively on compatible devices. The results of this methodology provide a valuable reference for WebVR PannellumJS framework in tourism, offering insights for corporate users, creative agencies, and developers aiming to leverage VR360 for enhanced audience engagement in digital communication.

## III. IMPLEMENTATION AND RESULT

### *A. Interaction Design*

The diagram below illustrates the system design (see in Fig. 1), where AngularJS was selected for developing the front-end of the application due to its numerous advantages, particularly those well-suited to our web360 functionality. Leveraging the MVC model applied by AngularJS, a Main Controller file manages the primary HTML file. This controller handles data flow from user input, processes it, and integrates it into the web360 environment to create 360-panoramas and enable further interactive actions.

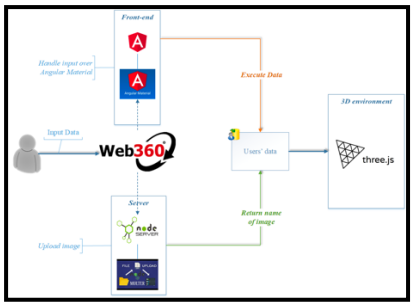


**Figure 1. Architecture System**

### *B. Development of the VR Tour*

#### *Data and Image Collection for 360 Panorama*

To conduct this study, data was gathered on Wat Phou, an ancient temple complex located at the base of the sacred Phou Kao mountain, also known as "Elephant Mountain". Historians regard Wat Phou as Laos' oldest temple, originally a Hindu sanctuary dedicated to Shiva. By the 13th century, it transitioned into a Buddhist temple, preserving significant historical and cultural values of Lao heritage. Over 12 representative 360-panoramics of the Wat Phou complex were collected to support this research.

To create high-quality 360-panoramic suitable for WebVR applications, the PTGui software was employed for image stitching, as presented in Fig. 2. Below are the fundamental steps in the 360-panoramic creation process using PTGui:

Preparing Images: A camera equipped with a wide-angle lens (fisheye or standard) was used to capture multiple shots from a single location, ensuring complete 360 panoramic coverage around the temple.

Importing Images into PTGui: Captured images were loaded into PTGui, where the software's algorithm aligns and stitches them based on matching points.

Aligning and Stitching: Automatic stitching results were reviewed using PTGui's "Align Images" function to enhance alignment accuracy. Manual adjustments were made as necessary by adding or correcting control points between images.

Editing and Optimisation: PTGui's editing tools were used to refine brightness, colour balance, and correct any visible stitching errors. The "Panorama Editor" mode ensured image quality without distortion or loss of detail.

Exporting the 360-panoramic: Upon completion, the final image was exported in an equirectangular format (JPEG or PNG) with a 2:1 ratio, the standard format for WebVR Tour.

**Figure 2. PTGui for 360 panoramic processing.**

This methodological approach ensures high-quality, immersive visual outputs for VR tour, enhancing users' virtual exploration of Wat Phou's historical and cultural landscape (see Fig. 3) .

**Figure 3. The picture 360-panoramic.**

***Development Tour VR360*** is an important step to enhance the user experience and create a unique 360-panoramic tour. The back-end technique using WebGL has become increasingly popular among developers, with libraries such as ThreeJS, PanoramaJS, PannellumJS, and BabylonJS gaining widespread interest. This study highlights PannellumJS, an open-source library that facilitates efficient 360-panoramic processing using WebGL, JavaScript, HTML5, and CSS3. Key terms include Scene, a 360-panoramic virtual "world" containing objects, such as: Hotspot, an object placed within the image to display information or link to another view; Pitch, allowing the camera to tilt up or down; Yaw, enabling left-right panning; Hfov, defining the camera's horizontal field of view; and Roll, which adjusts the horizon line of the image. This configuration allows for flexible, interactive 360-panoramic virtual tours, enhancing the user experience with intuitive navigation and accessible design. First of all, we added text, images, and other multimedia elements to the tour hotspots to allow additional information, such as descriptions, captions, and multimedia content, to enhance the user's understanding and enjoyment of the tour.

#### *Add Tour VR360*

To implement a VR360 tour, one begins by configuring JSON settings and initializing the viewer through a JavaScript API. This setup uses a spherical framework that applies the 360-panoramic as a texture on the inner surface, creating an immersive panoramic experience. Adjusting the Hfov (horizontal field of view) is essential for enhancing visual realism, while positioning the camera within the sphere and setting its target attribute ensures optimal viewing. Camera rotation can be controlled by either adjusting the camera's rotation attribute or designating a specific target point around which the camera orbits. The PannellumJS library streamlines this process, allowing developers to easily set the camera target to the sphere's center, thus facilitating smooth rotation and a comprehensive 360-panoramic perspective. This format fragments the spherical image into smaller, manageable squares, optimising performance and making it easier for browsers to render seamlessly, is showed as Fig. 4. Although optional, this step-known as "multiresolution" is recommended for smoother panoramic viewing. To perform this conversion, the generate.py script is employed, requiring Python3, and the Pillow and NumPy libraries. Virtual tour

packages can integrate multiple scenes and navigation, as demonstrated in Pannellum's tour documentation example (https://pannellum.org/documentation/examples/tour/).

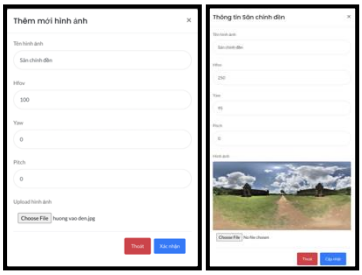


**Figure 4: Administrator function for adding new tour**

***Add Hotspots:***

Hotspots are interactive elements that link different panoramic photos together to create a seamless navigation experience. They also allow users to click on different parts of the panorama and explore them in more detail. By clicking on the "Hotspots" button and selecting the type of hotspot, it is possible to add text, images, videos, and other multimedia elements to the hotspots and customize their appearance, behavior, or properties (Fig. 5). By using hotspots creatively, one can enhance the visual storytelling of the tour and guide the audience through it. Adding hotspots can make the 360-panoramic tour more engaging, interactive, and memorable for the audience.

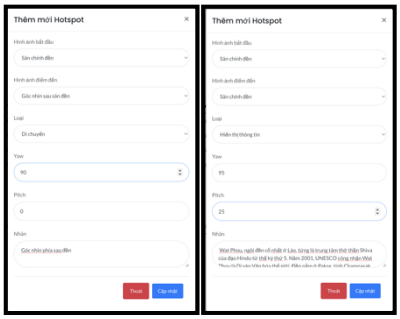


**Figure 5. Administrator function for adding new "hotspots".**

The preview phase is an important step in creating a 360-panoramic. During this phase, we previewed and tested the tour to ensure that everything works as expected and that the user experience is optimal. From there, it is possible to navigate through the tour, test the hotspots and multimedia content, and make any necessary adjustments. Preview mode also allows the testing of the tour on different devices and platforms to ensure that it is optimized for different screen sizes and resolutions and cross-browser compatibility.

***Publish the Tour VR360:***

The virtual tour of the cultural heritage site, Wat Phou in Laos, is available for download from link https://360watphou.online/ (accessed on: 01, May 2024), is illustrated in Fig. 6. This deployment methodology is versatile and can be scaled for use at any cultural location, providing numerous functionalities and applications, especially in the cultural heritage sector. In the field of archaeology, virtual tours offer a valuable tool that complements traditional surveying and graphic and photographic documentation techniques by capturing a comprehensive, panoramic view of an area in a single shot.

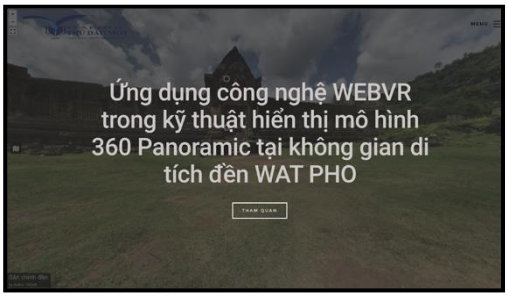


**Figure 6. The homepage of WebVR**

The created virtual tour primarily features spherical images and initiates in an "auto-rotate" mode, allowing the user to begin an interactive experience of the location immediately upon entry. The interface includes a slim bar that displays the title of the current scene, with a button to toggle the interactive map on the far-right side (see Fig. 7).

**Figure 7. The scene central of Wat Phou VR360**

Within each spherical image, arrows serve as "hotspot links" that allow navigation between scenes in a pre-defined sequence, simulating a physical tour path. Hovering over a hotspot displays a tooltip containing the name of the linked scene (Fig. 8).

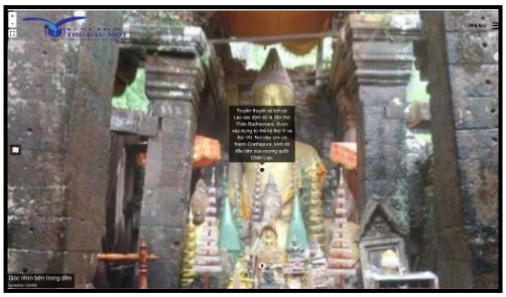

**Figure 8. "hotspots" describe information temple Badhe.**

A key feature of this project is the interactive map, accessible through a button at the top right. The button link provides a schematic layout of the site, with points on the map corresponding to the visible scenes in the virtual tour. These points serve as additional navigation options, supplementing

the hotspot links, and can be zoomed in or out as necessary (see in Fig. 9).

**Figure 9. The sence WebVR of behind Wat Phou**

Designed for compatibility across all device types, the virtual tour adapts seamlessly to mobile devices, where the spherical images and hotspots are slightly enlarged for ease of navigation. This virtual tour prototype was developed using spherical images captured at the cultural heritage site of Wat Phou, Laos, to test the effectiveness and applicability of the virtual tour model.

## IV. CONCLUSIONS

The WebVR project at Wat Phou not only promotes local tourism and cultural heritage but also alleviates pressure on heritage sites, contributing to sustainable preservation. WebVR technology has advanced heritage exploration by offering immersive, accessible virtual experiences, as seen with the Wat Phou site. This technology allows users to interact with cultural and historical content virtually, removing physical barriers and enhancing convenience. For tourism providers, WebVR promotes global engagement without impacting the actual sites, supporting sustainable tourism while generating new revenue streams. This study highlights future applications of VR360 in fields like real estate and encourages investment in VR360 for virtual tours, enhanced site information, and personnel training to maintain VR systems. This approach promises sustainable, innovative connections to cultural heritage.

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