Integrated Framework for Virtual Tours and 3D Visualization of Cultural Tourism in Pattani, Thailand Based on WebGIS Platform

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Abstract
This paper presents a framework for developing a lightweight WebGIS platform as a web map service for publishing and servicing cultural tourism information. The archaeological sites, history, and cultural arts in Pattani Province were used as case studies in this article. It incorporates various digital technologies to create digital archives in providing web-based information services, including geospatial databases, virtual tours and virtual reality, 3D models, and online cultural maps for tourism. The framework describes the necessary infrastructure based on open-source code that is specially developed and provides libraries with free software interoperability, which can be considered as a real-time data management facility and simple completion. It is a relatively low-cost but a *reasonably efficient system that is very useful and suitable for local authorities and small organizations with budget constraints to be able to implement practical cultural heritage management for a digital tourism experience that can be displayed on computer equipment, smartphones, and VR headgear efficiently. Furthermore, it also offers a conceptual framework in disclosing future research directions.*

Keywords: 3D WebGIS, Culture Mapping, Virtual Tours, VR WebGIS, Web Based GIS Framework

1. Introduction

In this decade, the ancient sites, Arts and culture are factors used by the United Nations Educational, Scientific, and Cultural Organization (UNESCO) and governments in setting policy alongside with the sustainable development goals to stimulate the growth of the creative economy or the creation of added value and exploitation of cultural assets to earn income [1] and [2]. Based on the aforementioned concepts, government agencies formulate strategies for campaigns that aim to preserve heritage and cultural assets, increase awareness and understanding of local and national cultures, share spaces for activities on multicultural dimensions, improve the direction of investment in cultural education, and promote incentives for tourism. Therefore, cultural tourism planning is one of the essential elements to promote revenue generation and sustainable development in the tourism industry [3].

Advances in virtual reality technology can provide a simulated method for a person to interact with perceived situation and experienced the environment as if they had actually entered the specified area. Currently, this technology is readily accessible to government agencies, private sector organizations, and the general public. In addition, another new technology available in the market is the 3D modeling, which combines many technologies. Among the technologies combined in 3D modelling are the integration of building modeling technology (BIM) with geographic information systems (GIS), 3D object modeling technology with software sculpting methods, or point cloud generation with photogrammetric methods that combined data from unmanned aerial vehicles with distance measurements by surveying methods. The aforementioned technologies can present virtual reality [4] and [5] and 3D representations of cultural objects when integrated with online maps from the free Google Maps platform, where users can view digital document datasets and browser-based services. This ability is forecasted to enrich the process of creating learning media, being a facilitator, and enhancing new experiences for travelers before traveling for real. It is both opening up opportunities and creating a new trajectory that will take place in the tourism industry in the next decade [6] [7] and [8].

However, web-based geospatial development (WebGIS) in a way that provides interactive and reliable information about cultural sites also has a separate framework and display depending on the technology used, and there is a programming complexity that varies between source codes and libraries depending on the system architecture and usage conditions [9] and [10]. As mentioned above, there is a new challenge pertaining to the methodology-based framework for geospatial and contextual data services in the form of a web-based geospatial system that integrates GIS-VR-3D model-internet technology to provide services that can be accessed through the internet network [11] and [12].

The structure of the article begin with the design and development of a framework with an open-source code suite that incorporates the WebGIS platform for developing a database function [13] and [14], an online cultural mapping service system, and an information display virtual tour of environments, using free software to create 3D models that are processed using the photogrammetry method [15]. The second part of the article presents the system architecture that supports the technology. GIS-VR-3Dmodel-internet consisting of a combination of hardware, software, and connection protocols for collective functioning, which define a framework on how the system and the internal model operate alongside with the data preparation in accordance with spatial data [16] and [17]. The next part presents the results of the system user satisfaction assessment. Finally, this paper concludes with conclusion, suggestion and ideas for future research direction.

2. Research Background

2.1 Definition of WebGIS

WebGIS can be referred to by a different acronym, such as Web-Geographic Information System (GIS), Web GIS online, or geospatial service, which is a geographic information system on the internet, but has a narrower meaning and is more commonly used due to the meaning being simple. WebGIS is a particular type of distributed information system which requires at least one server and one client, a system that may display data and service online map data, geospatial data, and GIS functions as well as provide any specific way that facilitates or makes available to the public depending on the website's content and enables, a collaboration between users using a unique uniform resource locator (Url) to create searchable online services, wherewith data transmission, and other component functionality is a standardized service of the Open Geospatial Consortium (OGC) specifications, in addition, the architecture system utilized to information service differs depending upon the developer, resources, budget and capabilities of each organization [18] [19] [20] and [21].

The Web GIS development procedure focuses on designing a framework for developing platforms using various technologies, in accordance with the system standards developed by the Open Geospatial Consortium and ISO 19142 [22]. A web mapping server v1.3.0 was prepared by Technical Committee ISO/TC 211, web mapping server v1.3.0 [23] and [24], with exchange and transmission, modification, update, replace, delete, and display of both vector and raster data, such as shapefile, CSV, GML, JSON, GeoTIFF, and jpg file formats, to serve web map service (WMS) revealed image data services such as online mapping, 3Dmodel, virtual reality image sets, and document file formats of culture and the ancient site of Pattani province, Thailand.

2.2 Study Area

The study area covers Pattani province in southern Thailand, with a population of 729,581 people in 2022, and is administratively centralized into 12 districts. The region is part of a narrow peninsula, mostly flat and low-lying, with a tropical monsoon climate (Am). It is hot in summer, and during the rainy season, from November to December, the northeast monsoon brings cold and wet air from the Gulf of Thailand and the South China Sea over major parts of the east coast south of Thailand, with a mean annual rainfall of 1,900-2,400 mm and a temperature range of 23-32 °C. The Fine Arts Department has recognized 21 ancient sites, while 31 more are being included into the database for registration (Figure 1).

History of Pattani province: From the evidence of archaeological documents in relation to Pattani, it appears that the name of an important city on the Malay Peninsula is pronounced according to the accent in each language, such as Lang-Ya-hsiu (Chinese), Langkasoka (Sanskrit), Ilangkasoka (Tamil), Lengkusa (Javanese), and Langkasuka (Malay) whereby these names are assumed to refer to the same city. The city may have an administrative center in Pattani Province, Thailand, or Kedah State, Malaysia. Nevertheless. from the evidence of the excavated Yarang ancient. monument, there is evidence of the remains of 3 large ancient cities overlapping, consisting of the ancient Ban Wat, Ban Jale, and Ban Prawae. There are pieces of ancient objects found at those mentioned locations such as a bronze head of Avalokitesvara, pieces of the miniature stupas, antique pieces and fragments of pottery for aged Buddhist places that were accessible and enshrined in Mahayana Buddhism, around the 12th to 13th centuries.

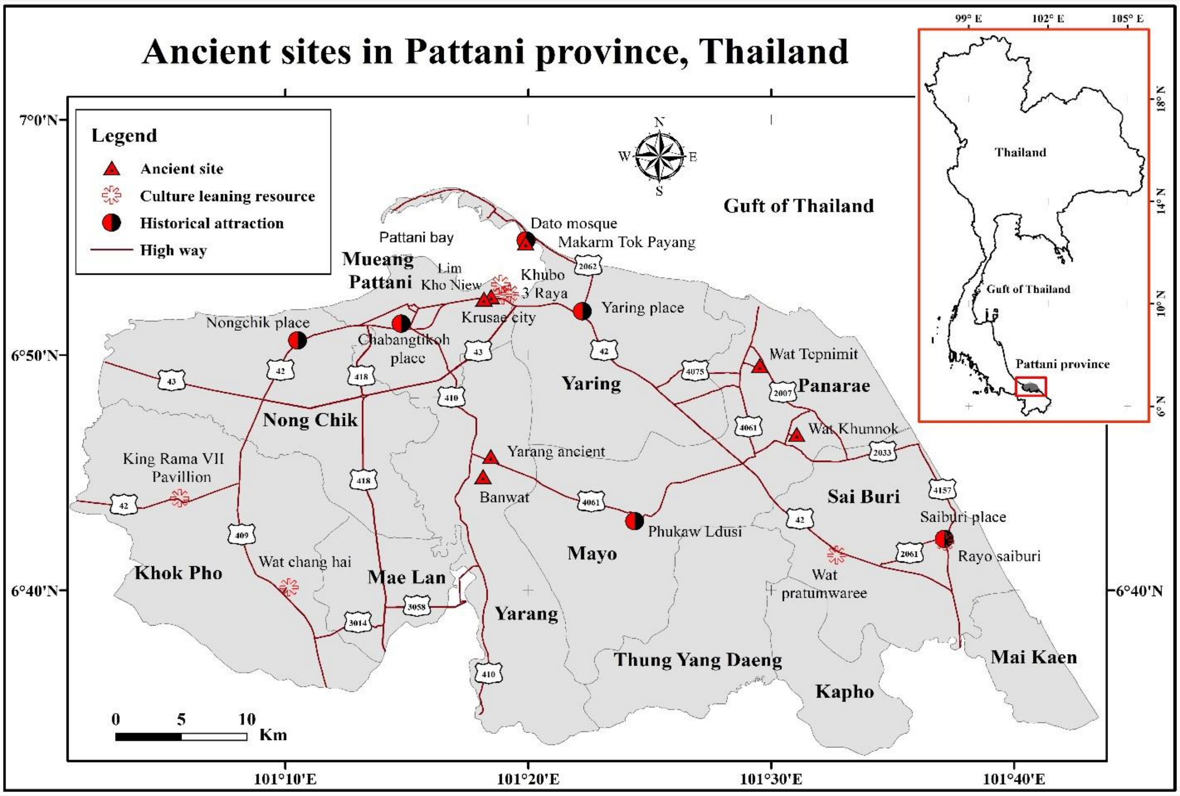

Figure 1: Map of the study area in Pattani province, Thailand

Some of them are recorded in Pallava alphabets (Pallava kingdom in South India), while others have written incantations in Sanskrit in Mahayana Buddhism. There are many more reliable evidence found indicating that the center of this ancient kingdom was probably located in Pattani Province, Thailand [25].

2.3 Requirement Analysis

2.3.1 User requirement

The WebGIS application has been developed with the following types of users in thoughts namely, administrators, government officials, information workers, academics, researchers, tourists, and the general public. Administrator: refers to the person who has access to and administers the data as well as all system procedures, such as granting rights for access to various parts of the service to other users, alongside with taking responsibilities for system maintenance. Government officials in this context refers to academics, and researchers who can import data and prepare data for information presentation to groups of tourists and the general public, hence having access to download files of documents and information for various purposes. Tourists and the general public: are users of the service, which the system will assist in facilitating travel, information search, use of online maps to identify travel locations, visibility of 360 panoramic images and virtual reality. Consequently, information provided to the tourist will facilitate travel, and learning experiences at the ancient sites, cultural sites, etc.

2.3.2 System requirement

This development of WebGIS employs a client-server architecture as a fundamental system to support a web-based information service system, choosing a three-tier architecture with the concept of distinguishing the functions of each tier**.** consisting of the followings;

1) The presentation tier or the user interface (UI) is the display and input interface, which uses the model-view-controller (MVC) system architecture concept, where the model is a function of receiving and transmitting data from the application logic tier. View is a conditional display of the controller, regardless of the data structure. In addition, the function of the controller is to control the conditions that are intermediaries between the client and the server, which will be receiving and transmitting data from the Model while subsequently sending it to View to display results according to user's conditions.

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2) Application logic tier or Application tier is the processing function to regulate the operation in accordance to the conditions.

3) Database tier or Data storage refers to the function that manages and communicates the database to provide the required services. The characteristics of the system components are as follows:

Hardware and Software:
In this development, the server-side utilizes hardware features such as CPU 3.8 GHz and RAM 16 GB, and the server-side software uses Windows/Apache/My SQL/PHP (WAMP suite) format, (Figure 2) including the Windows Server 2019 operating system. The Open Geospatial Consortium (OGC) compliant and standards-compliant open-source platform consists of the Apache web server v2.4.45, which provides interoperability, library access permissions, the ability of management to debug, high-end security and protection features, the MySQL v5.6 database system, and PHP v7 server-side scripting software for effective database and user interaction. This system has the advantage of being able to deal with vast quantities of data well. However, the disadvantage is that it is burdensome and requires a person with experience in creating a set of codes to integrate protocols with various technologies to be able to function together.

Source Code Framework:
In this context it develops an environment on the framework by programming various web languages, such as HTML and CSS codes for document formatting and PHP v.7 and SQL 5.6 codes for administering MySQL databases. It uses JavaScript, asynchronous JavaScript, and XML (Ajax) code to create interactive web pages from refreshments to animated displays and interactive maps. The Google Map API library, Javascript, JQuery, an online mapping platform and the A-Frame library [26], the ThreeJS in a 3D modeling platform on the web [27]. and Panellum's library of programs for virtual tour platforms, etc are also being applied/ used [28].

Domain and Protocol:
The choice of display domain is essential to be considered since online mapping platforms, virtual tours, and 3D modeling can be rendered on any Hypertext Transfer Protocol (HTTP) domain. and Hypertext Transfer Protocol Secure (HTTPs), while virtual reality platforms and 3D models on A-Frame libraries will only render rich images on the https domain. Development in this area is therefore recommended. HTTPS domain with an SSL certificate is being installed because the Secure Socket Layer (SSL) and Transport Layer Security (TLS) protocols are to check encrypt data in transit, whereby they secure websites and protect highly sensitive information better than HTTP. However, if an organization uses the http domain, therefore it is recommended to use Firebase web hosting, which offers 10GB of free server space for hosting virtual reality and 3D modeling platforms on the A-Frame library.

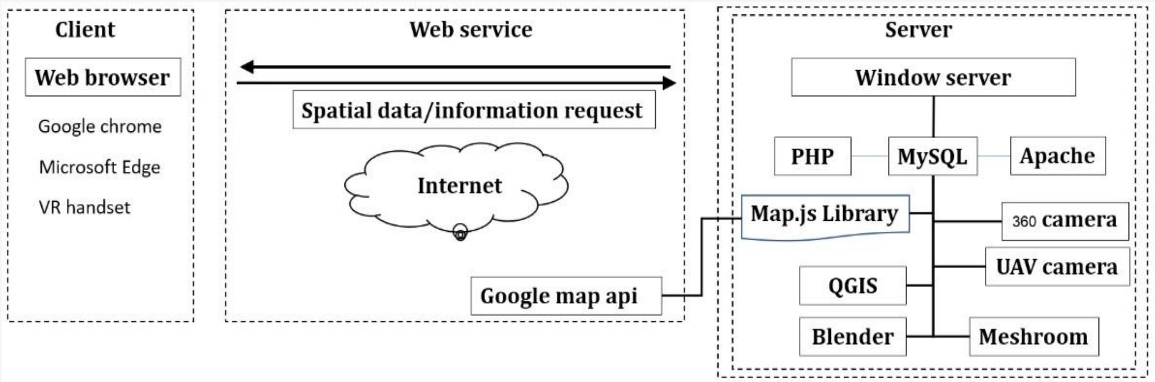

Figure 2: Architecture system of Pattani culture online map: WMS conceptual framework

Application Free Software Package:
This framework introduces the use of free software for 3D modeling, which is free of charge. It can help reduce agency software licensing fees while providing immense potential and supporting work efficacy. Selection of the program for development are categorized into four parts as follows:

Part One: 3D modeling Procedures for 3D modeling with Meshroom v. 2020 [29] are presented as follows: 1) Image dataset acquisition using DJI Mini 2 and Huawei Lite P30, 2) Image datasets were processed using photogrammetry to create a point cloud, 3) Texture pattern creation procedure, 4) Model refining Using MeshLab r2020a [30], point cloud boundaries, and textures, and 5) exporting model data.

Part Two: Apply Blender v. 2.93 LTS for graphics rendering and UV mapping, rendering, model modification [31], and exporting the model to the web page. There are 2 workflows listed as follows:

I) Correction and enhancement of model data from Meshroom v. 2020 processing using model editing, sculpting, UV mapping, rendering, and shading functions, etc.

II) Programming source code is being concerted to A-Frame and ThreeJS libraries in order to manage queries from clients or to send 3D model data to web services in conjunction with online maps or display on web pages.

Part Three: Shapefile creation of data, for data collection and digitization in shapefile format, the researcher used Quantum Geographic Information System (QGIS) v3.16 Hanover [32], which can be downloaded at the URL https://download.qgis.org/downloads/. QGIS is a free software that enables users to generate, revise, analyze, and publish geographic data. Additionally, raster, vector, and geometry layers are being supported, where vector data is saved as points, lines, or polygons and then converted to kml or kmz files for web presentation.

Part Four: In creating a Virtual Tour, the Instr360 OX2 and Huawei Panorama 360 Envizion2 cameras are being used to record using the free software Desktop Studio, and the Huawei 360 camera for exporting the images correspondingly. The image data set is used to enhance the quality and create attractive images with Photoscape X, then sorted and imported to the database for retrieval in further displays.

3. Research Methodology and Data Sets

The development of WebGIS is an integrated framework for developing a Web map service (WMS) online cultural mapping platform using a lightweight programming method in an open-source code aimed at providing tourism services to ancient sites and cultural learning institutions in Pattani Province, Thailand. Applications can be accessed through a browser that renders web pages as an interactive interface and associates rendering with computer-generated imagery (CGI), consisting of a series of tourism images from virtual tour technology and 3D models of ancient locations derived from photogrammetry technology [33]. The tourist attraction information refers to the geographic location based on the actual location. Data storage and management use a relational database management system (RDBMS), but in some functions, a specific approach (Ad hoc approach) is used for solving a specific problem in a specific task, where there is no need to look at the overview of the system. (There are no details in this article.) The framework is divided into various phases, as mentioned in detail below.

3.1 Document Analysis

The researcher established a framework to analyze art, culture, and historical sources for the purpose of serving as annotations and explanations for panoramic photos, virtual tours, 3D image processing suites, and online maps. It collects non-spatial data from secondary documents regarding art, culture, archeology, and history from reference able sources, in the form of data files, books, research articles, other publications, personal statements, etc. The collection of primary documents was conducted through informal interviews with a sample of ten distinguished individuals who are key informants, including community leaders and sages in the community. which emphasized collaborative learning with members of the community and local authorities. Moreover, field surveys are conducted at the cultural sites, historical learning sites, archaeological sites, etc. The archaeological sites used as a case study in this research are Yarang Ancient City, Krue Sae Mosque, Toh Payae Mausoleum, Thepnimit Temple, Dato Mosque, Wat Hongsaram Temple and Khuan Nai Temple. Document content analysis and synthesis: The collected and surveyed information is categorized according to the content type. The information obtained from the interviews will be summarized for each subject, then it is ready to be digitally documented and stored in the MySQL database for retrieval and display on the website.

Digital document archives save files in different formats, including text files containing files with the extensions *.txt, *.docx, and *.xlsx; audio files with the extensions *.mp3, *.wma, and *.wav; video files or motion graphic files stored in *.mp4; and image dataset files saved in *.jpg and *.png.

3.2 Geographic Databases and Online Mapping

Geospatial data generation on the web uses the same format as GIS on personal computers, which provides data in two feature types: spatial data (either vector or raster data type) and non-spatial data. The collected and synthesized documents and data are preserved in the form of digital document files of the natural feature and stored in the MySQL database; the spatial database has a framework in 2 parts as follows (Figure 3).

Part One: Using Geographic Information Programs: This part applies the QGIS v3.16 Hanover program for generating spatial data or data related to geographic locations, including raster data or grid cell data, save files in *.tiff and *.img formats, as well as vector data formats and feature description data such as point, line, and polygon, which save files in shapefile format. The shapefile data is converted to image data files. Keyhole Markup Language (Kml) and/or Keyhole Markup Language Zipped (kmz), which provide syntax and an Extensible Markup Language (XML) file format for display are used javascript in conjunction with the Google Maps API and Google Earth, the kml files are uploaded to the MySQL database, where the kml file has web rendering requirements for running on HTTPS domains, so organizations using HTTP domains can upload to the HTTPS web hosting provided. public and free service; whereby at this juncture, we recommend GitHub and Firebase hosting. After uploading, it can then refer to the local repository files for accessing the map service data with source code developed for use with the Google Maps API.

This research defines a spatial data layer consisting of namely; an infrastructure database consisting of administrative boundaries at the village, sub-district, district, province, and country levels, transportation routes, and waterways, together with the developed database including archaeological sites, tourist attractions, accommodations, and restaurants, with data collected from the mission survey work of the project. The geodatabase is based on the Fundamental Geographic Data Set (FGDS) defined by the National Geo-Informatics Board, Thailand, which requires the use of a geographic coordinate system with an ellipsoidal reference base of the World Geodetic System 1984 (WGS84) Zone 47N, or coded according to European Petroleum Survey Group (EPSG) code EPSG 4326.

Part Two: Geodatabase: Designing and storing content in the database table format is performed in a MySQL database by taking digital documents in *.xlsx, *.txt, *.docx, or other formats and storing them in the database table, such as the location of the hotspot coordinates, the 360-degree panoramic coordinates of the cultural attractions which will be the first marker point or landmark that link to the virtual tour content of that place, a 3D model database, an orthophoto database, or other relevant databases as necessary. Database quality management focuses on the normalization processes to reduce redundancy, avoid anomalies, and reduce storage size. The data in these database tables will be displayed as online maps on Google Maps by writing PHP and SQL source code with JavaScript and the Google Map API.

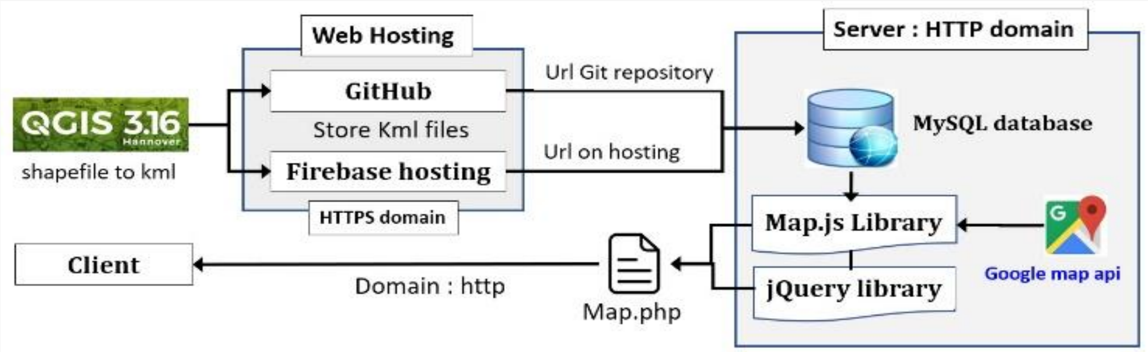

Figure 3: Framework for geographic data within the Google maps API, specifically for http domain

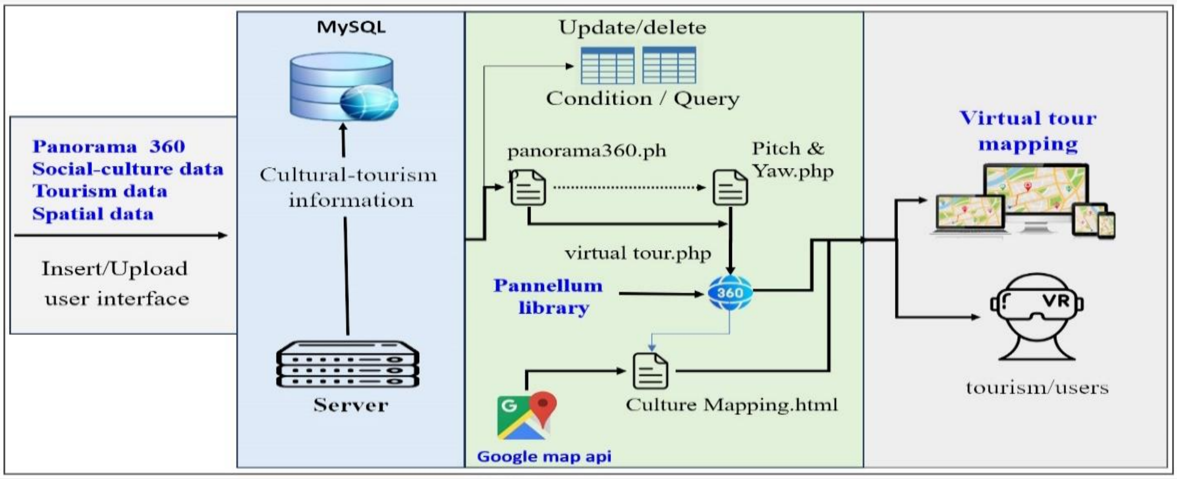

Figure 4: Workflow for designing of virtual tours and maps

3.3 Virtual Reality (VR)

Virtual Reality Tour is a revolutionary virtual reality technology that uses 360-degree panoramas to recreate the real world in a computer-simulated environment. It is based on open-source code and uses the Pannellum library to locate hotspots on image datasets in a database and link documents to online mapping services via the Google Maps API, illustrated in the following sections (Figure 4).

3.3.1Collection information

Collection of information used the Insta360 oneX2 camera to collect the panorama 360 image dataset, recording an image size of 6080 x 3040 px (2:1) and resolution of 96 px/inch; a file is in Insp format that can be converted to jpg using Arashi Vision Inc.'s desktop studio program; along with Huawei 360 panorama cameras, recorded using the Huawei 360 Camera application, with an image size of 5376 x 2688 px and a resolution of 350 px/inch, whereby The image is in equirectangular format but can be provided either as a cube map or in sphere format. This preparation focuses on the equirectangular, which is the most basic requiring only one picture. Nevertheless, in ensuring picture data utilization and presentation, the maximum width of the picture size should be limited to 8192 x 4096 px, which is the maximum image size supported by most headset devices. Photos documented and intended for display in virtual reality tours undergo quality enhancements such as vibrance, hue, saturation, brightness, contrast, and so on to produce a more complete picture that is colorful, appealing, and clearly articulated. Exporting photographs is suggested in *.JPG format, but alternatively the user may use one of these formats, such as *.PNG or *.TIFF, in conjunction with the shooting location of each picture's panorama.

3.3.2 Get the coordinates of equirectangular image and a hotspot

The framework for adding hotspot locations for linkages or displaying content descriptions on equirectangular pictures to other images has been developed in JavaScript using the Pannellum library, which is built from Python scripts and is supported on WebGL. The parameters used to identify the position of the hotspot marker and the angle of view on the 360-degree panoramic picture are all related to the 3D image rotation axis. However, the original image has two-dimensional (X, Y) coordinates. Therefore, in order to solve the problem of coordinating the conversion of different systems and allowing officers to work easily and quickly, the researchers developed open-source code with JavaScript and Pannellum's library built with Python and JavaScript that can display the location of hotspot markers and angle of view (FOV) in pitch and yaw format on 360-degree panoramic images, according to the framework as follows:

I: The parameter for getting the location value of a hotspot in an equirectangular 360-degree panorama used the principle of rotation around the center of gravity. Therefore, the reference coordinate system for the image's hotspot mark is related to the three-dimensional rotation axes, such as the axes of pitch, yaw, and roll, which are determined using the axes' vertical rotation or movement around the axis (vertical axis), where pitch is a view up and down along the vertical rotation (relative to the Y-axis). Yaw is the left-right perspective along the vertical rotation (relative to the X-axis), and roll is the vertical axis of rotation.

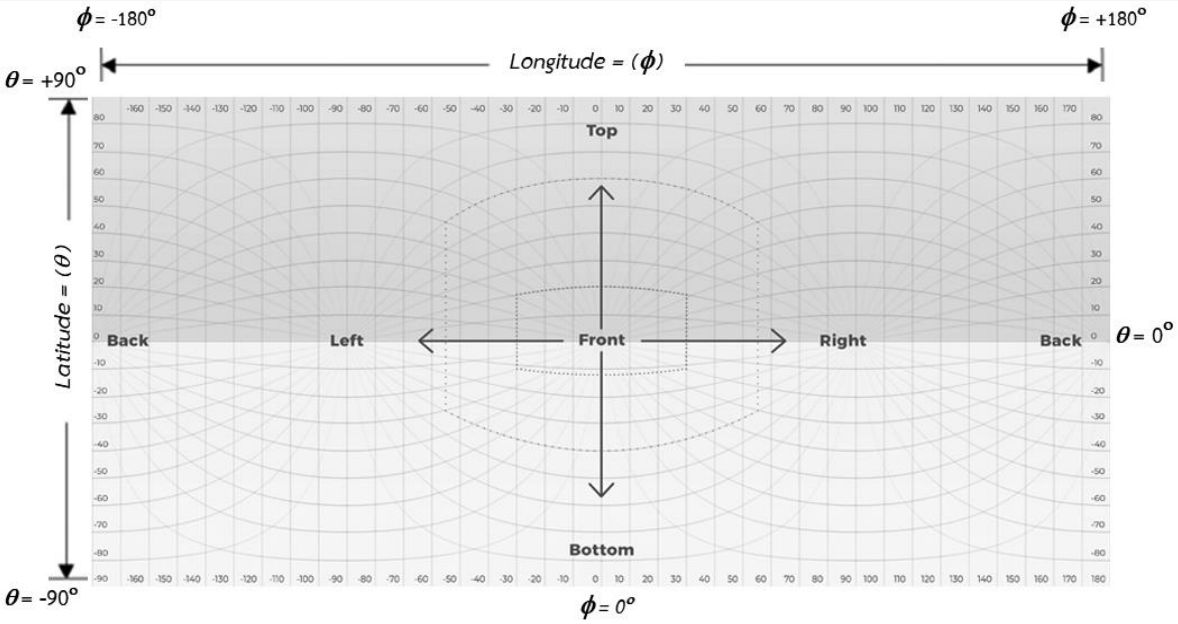

Figure 5: Equirectangular mapping projection and coordinate system that utilizes geographic coordinates

For the creation of a virtual reality model, equirectangular panorama simulation applies a mathematical method that converts image points from a geographic coordinate system into three-dimensional motion when an item moves through a medium. Pitch and Yaw pixel coordinates are calculated using Equations 1 and 3. The bottom left corner of the picture is commonly referred to as the image's genesis point. Whereas in virtual reality simulations, the origin coordinates are configured to relate to geographic coordinates or to the center of the image, which has the X-axis representing the plane of longitude and the Y-axis representing the plane of latitude (Figure 5).

II: The following mathematical formulas are used to convert equirectangular panoramic pixel data to the pitch and yaw axis coordinates of a virtual reality image. The yaw can be defined as a formula by converting image point coordinates to geographic coordinates using the ratio of 180 to half the image size, multiplied by the coordinates of the image spot, and subtracted by 180 which can be written as a formula, as in Equation 1 to Equation 4. The yaw ***(ϕ)*** or rotation coordinate along the axis of X can be calculated from Equation 1:

$$\phi = \left[\frac{360 M_x}{Rhp} \right] - 180$$

Equation 1

where:

Rhp = the number of pixels horizontally based on the image's width

M_x = the mouse's position in the X axis, resulted from Equation 2:

$$M_x = e.pageX - offset.left$$

Equation 2

where:

e.pageX = the X-axis coordinate of the mouse cursor when the mouse button is clicked upon

offset.left = the horizontal coordinate value of an image pixel in reference to the picture's left edge when the mouse button is clicked upon.

The pitch (Θ) or rotation coordinate along the axis of Y can be calculated from Equation 3:

$$\theta = \left[\frac{180 M_y}{Rhp} \right] - 90$$

Equation 3

where:

Rwp = the number of pixels vertically based on the image's width

My = the mouse's position in the Y axis, which results from equation 4:

$$M_y = e.pageY - offset.left$$

Equation 4

where:

e.pageY = the Y-axis coordinate of the mouse cursor when the mouse button is clicked upon, *offset.top* = the vertical coordinate value of an image pixel in reference to the picture's top edge when the mouse button is clicked.

3.4 3D Model on WebGIS

A framework that generates 3D models to be presented on websites and online maps integrates two methods: processing overlapping picture data from UAVs and smartphone camera photography series using free photogrammetry software. Sculpting techniques are also used to enhance the texture and provide light and shadow to three-dimensional models. The modeling process is described as follows:

3.4.1 Collecting information

The compilation of double-overlay image datasets is separated into two situations illustrated as follows:

Case one: In the case of outdoors, the compilation of overlapping image datasets using DJI Mavic Pro and DJI Mini2 is captured to take photos of a study area, control flying via Pix4D Capture's autonomous program, with a coverage area of approximately 150 m2, an altitude above ground level of 40–50 m, and recording the storage of the image data as a digital file in *.jpg format. The flight plan settings are specified in the following two categories:

1) Double Grid mission, including overlap 80% and side lap 60%, a flying speed of 3-5 m/s, a flight duration of 15–18 minutes, and a forward flight line through photography. The geolocation of image information is determined by the configuration of the Unmanned Aerial Vehicle (UAV) satellite receiver (GPS data (lat, lon, alt)), that refers to the Ground Sampling Distance (GSD) of picture collection in the range of 1.4 to 1.75 cm/px.

2) Circle mission type sets the flight characteristics to have an overlap angle of 8 degrees from the center of flight, with an area coverage of 150 m2 and 200 m2, a flight speed of 3-5 m/s, a clockwise loop in front of the camera facing the center of flight, and a GSD that varies with flight area size, and the dataset in the range of 2.65 to 3.39 cm/px.

Case two: In the case of indoors, the compilation of overlapping image datasets using DJI Mini2 and Huawei Lite P30 phone cameras has a 32 MP front camera with an ISO sensitivity of 800-1600s and a fixed exposure time of 1/60s, a fixed lens of 16 mm, and an ultra-wide-angle lens, in the act of taking photographs of an object from a distance of 1.5–3 m. Photography is defined as a forward overlap of 70–80% of the image. 6–8 image distance control points whereby it was set per image set and measured with a Leica D510, which has an error of +/- 1.0 mm and measures in the range of 1-200 m. The GSD of this image collection is the range of 1.4 to 1.75 cm/px.

3.4.2 3D Model photogrammetry processing

Accurate and realistic 3D modeling of cultural artifacts is vital because it is sensitive to the sentiments of the people who own the culture. Therefore, in this task, one must be subtle and attentive to the loss or deformation of the object's contour. If a person has knowledge and expertise in molding, it will assist them in working efficiently and swiftly. This framework offers a free software program to enable rapid and simple 3D modeling. Although individuals with less experience can learn and work, it is advisable to utilize Meshroom v. 2019 and Blender v. 2.93 applications with the following instructions (Figure 6).

Meshroom v2019 is a free program that comprises of a photogrammetry pipeline to build 3D modeling results from picture datasets, a node-based solution with parameters, and a high-level interface that may be customized. to meet creative and/or technological demands, making it available to anyone without the need for modification. The photogramgraphic approach comprises of two key steps: (1) Structure from Motion (SfM), which infers stiff scene structure (3D points) from the pose (position and orientation) and investigation, Internal comparison of all cameras for processing picture files obtained from UAV devices and cellphones, The final result is a collection of calibrated cameras matching a cluster of point clouds distributed, and (2) Multi-View Stereo (MVS) as a technique of creating perfect geometric texture by constructing a textured mesh. There are five key processes in modeling, each of which, after hitting the Start button, is automatically performed by the software. When the computation is completed, each step will be displayed in a green tab (the "Green Tab") as follows:

1) Import and sort, The photographic datasets to be processed should be named in the order of images and rows uniformly across the area of interest. The digital file type utilizes the *.jpg format, and images feature RGB color mode.

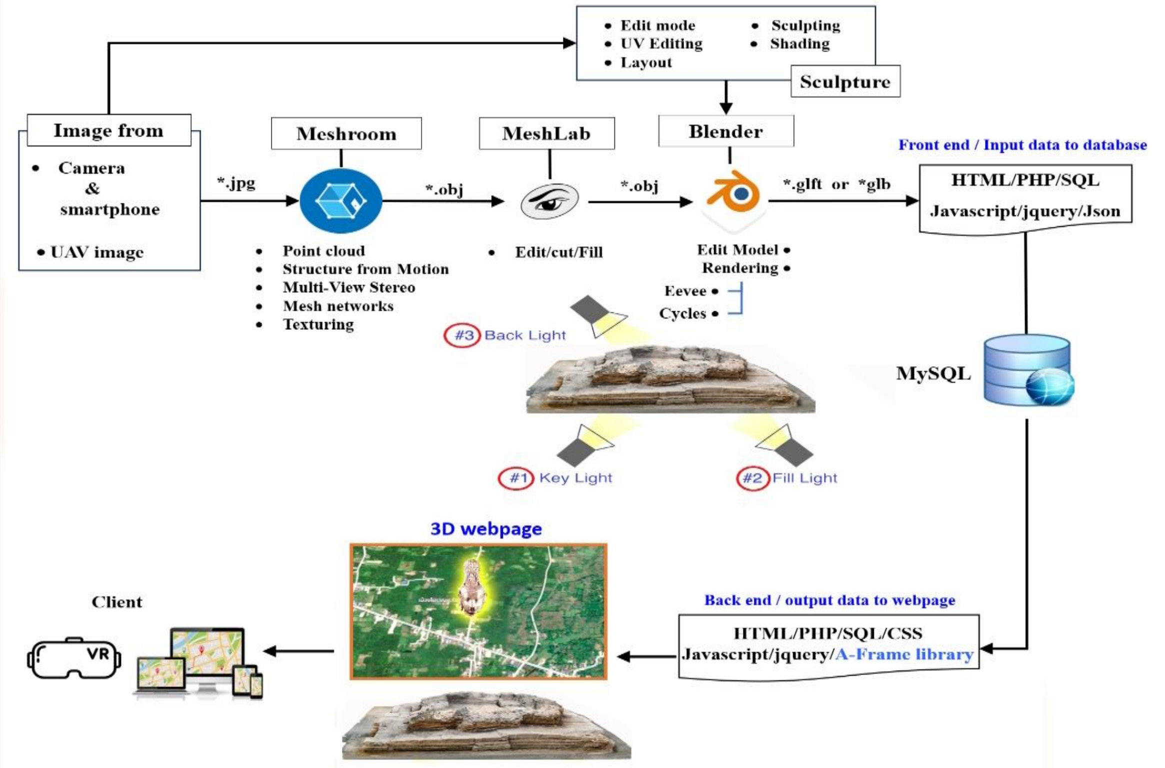

Figure 6: Workflow for designing 3D model and maps

2) Point data processing, continuous pixel data will be processed to build a collection of point clouds utilizing SMF techniques, resulting in point data that match coordinates location using the three-axis orthogonal coordinate system (x,y,z) or the Cartesian coordinate system. In the following phase, SFM technique results are automatically imported, and the MVS method is used to build dense geometric surfaces, which constitute mesh processing; the completed result is a texture mesh file (in OBJ file format with the associated MTL file). The MVS consists of producing depth maps for each camera, integrating them, and using this huge quantity of data to produce a surface. The creation of such depth maps is currently the most computationally intensive element of the operation. Therefore, requiring powerful processing hardware at least 8GB of RAM with a Nvidia GPU or CUDA 2GB or more-for creating a high-quality dense cloud, it is most advisable to utilize 32GB of RAM or more.

3) Post-processing: This is a step to simplify the mesh network and generate a low-poly 3D model (Retopology) by utilizing automated mesh decomposition. If model surfaces are required to have higher integrity, they can be set for iterative computations. The application adapts the settings to fit the demands, for example by setting the maximum number of vertices to 100,000 or adding the value (Steps 2 and 3 may take quite a long time, approximately 2-3 hours, depending on the computer's processing capabilities and the number of photographs.).

4) Retexturing after Retopology: proposed the IoU evaluation results from Convolutional Neural Network (CNN) classification to generate a 3D model showing that the overall accuracy of point cloud classification with RGB images was a little higher than non-RGB images [34]. However, retexturing after retopology is required. This is a technique that modifies the surface network of the original model. Techniques such as iterative refinement, retexturing, and retopology at this step can result in increasing or decreasing the number of surface networks in the new model or may generate a sharper new model. It can grow worse since it reshapes the model surface; additionally, it may also reduce or increase the file size. Therefore, it should be discreetly done because once the original model has been modified, it cannot be reversed (The data file should be backed up before working on it.). When the computations in each phase are done, export results utilize the *Obj file format.

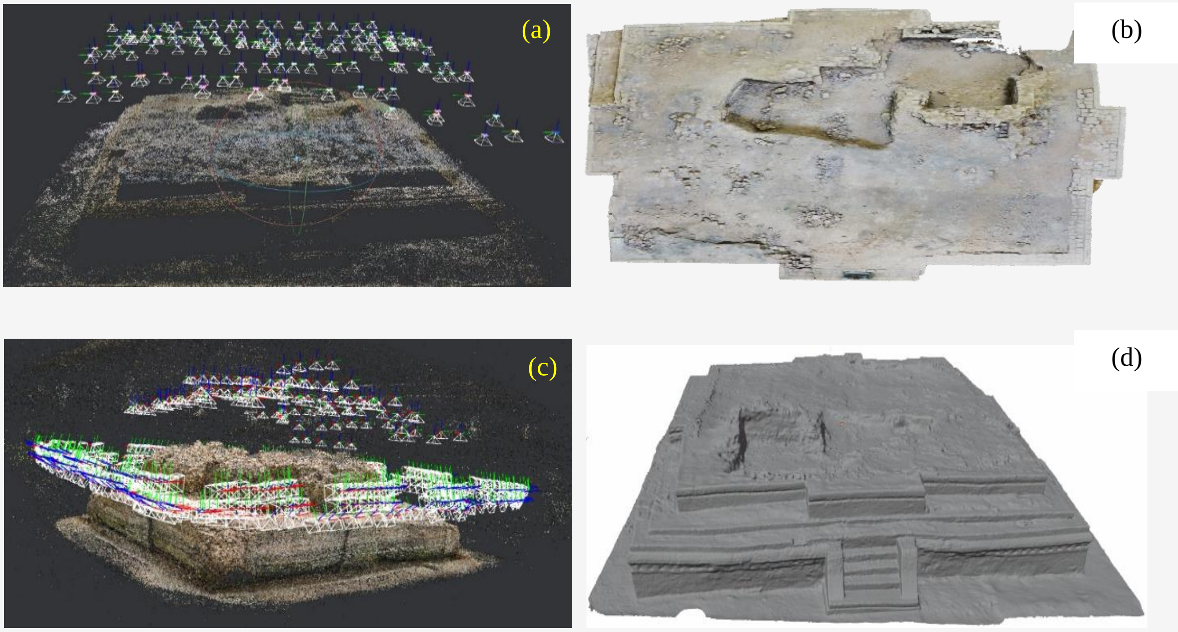

Figure 7: 3D model of the Yarang archaeological site reconstructed in Meshroom showcasing the camera position and texture of the imaging dataset used for 3D modeling (a) point cloud of the 3D model from the top-view imaging position (b) the resulting textured mesh from the DJI mini2 dataset (c) point cloud of a 3D model from combining images of the DJI Mini 2 with the Huawei Lite P30 camera, generated via the structure-from-motion method (d) the result of a dense cloud model from draft mesh generation using the multiview-stereo method (SFM reconstruction)

5) The result is exported for modifying the surface shape with the program MeshLab, then exported in *Obj file format to generate rendering 3D objects using the program Blender v2.93, and finally exported as *.glb for further display on websites.

3.4.3 Sculpture and 3D Model Processing

Sculpture is a suitable method for those with artistic skills or sculpture experience. This framework presents model reconstruction, reconstruction of missing textures, and reconfiguration of texture networks that cannot completely reproduce the texture in the programmatic process of Meshroom. Blender v2.9 in sculpture mode was used to create this effect. Although it's an effective and excellent method to display texture, this method is difficult, time-consuming, and requires a person with specific skills and expertise. Nonetheless, this addresses the problem and reduces the constraints on the number of polygons in the model surface network and the number of mesh networks, which will result in the model having a small file size and rendering in less time. Once the procedure is completed, the results can be exported in *.Obj format (Figure 7). Blender offers a broad range of advanced modeling functions. Users can implement additional functions themselves, such as an addon for Retopology or Modify Decimate Collapse, to reduce the number of polygons and collapses. However, users have to be cautious of the loss of texture details whereby once reprocessed, it cannot be reversed, hence requiring the original data file to be backed up. Furthermore, it is recommended to modify using the UV mapping method of texture creation, which can create a texture by using a suitable image as a texture that can be reversed and corrected with authentic details. In terms of the condition of the object or environment, if a skilled or savvy person uses this method, it can provide an efficient modeling and virtual environment based on the present moment. Finally, the file can be exported as *.glb and *.gltf for further display on the website.

3.4.4 Upload results on websites

Results files in *.glb and *.glTF formats were uploaded to the MySQL database with PHP and SQL source code development for database management, online map linking, and reporting for visualizing and publishing shared data on the web. Image display. Data dissemination systems use source code framework programming methods in map script with PHP v7, SQL, Javascript, and the A-Frame library to retrieve models from the database to display on a computer monitor.

However, if the model file is large (>100 MB) or complex, the browser may slow down, stall, or not display. Complex models designed with high-fidelity rendering are not suitable for real-time use in this system. Therefore, it is recommended to retopology the number of faces and mesh network on a model in the Blender program, and if the file size is too large, a decimate modifier may help flatten it out. The suggested Model file sizes are in the 5-100 MB range. It is simpler to be displayed on a PC than on a smartphone. Therefore, it is recommended to evaluate the model display on the screen at a frame rate of 24 fps on a display screen with a refresh rate of 60 Hz.

3.5 System Satisfaction Assessment

Data collection was done using a satisfaction survey questionnaire by selecting a sample group through the purposive sampling method whereby 30 different people expressed their opinions on the use of the service and the demonstration of the developed system. The characteristics of the sample were classified into Group 1, with a sample of 20 individuals with the characteristics of tourists, entrepreneurs, community leaders, and students. On the other hand, the second group consisted of 10 samples from the group of information officers, academicians, and officials related to arts, culture, and tourism, as well as officers of sub-district administrative organizations in Pattani Province. The designed questionnaire used a 5-tier Likert rating scale namely least satisfied, less satisfied, moderately satisfied, very satisfied, and most satisfied. Interpretation is based on the mean and standard deviation. The mean range was divided into 5 strata, with each stratum equal to 0.8, the lowest value being 1.0, and the highest being 5.0. In addition, the mean differences between the two groups were compared by T-test independent sample at. 0.05 Degree of Freedom (df) = 28.

4. Results and System Performance

4.1 Function of the System

As of Now, the development of the Web GIS framework includes open-source code and libraries for storing and managing databases, mapping scripts for online maps, the Pannellum library, and an A-Frame library for visualization, rendering, and improving images in virtual tours that show results with computer-generated imagery. It also covers photogrammetry applications for free 3D modeling software to prepare digital documents for serving and disseminating cultural tourism information on three platforms, namely: online culture maps, virtual tours, and 3D models, which can operate together as a standardized Web map service. For practitioners new to WebGIS, this framework can simply help develop understanding and implementation. The end-user can be easily accessed via online maps or with a list navigation toolbar. It is elaborated in detail in the following system components.

4.1.1Geographic database

The web map service system (WMS) for service consists of 18 basic databases, including tables of administrative boundaries at the level of villages, sub-districts, districts, provinces, transportation routes, historical sites, tourist attractions, accommodation, and restaurants, forest areas, geology, soil series data, topography, conservation areas, key informant and user, orthophoto data sets with 360-degree panoramic datasets, 3D modeling, and cultural digital documents. Framework for the back-end or operator provides an open-source code and flowchart with basic capabilities for database administration tasks such as user authentication, import, search, revision, deletion, and reporting information on web pages. The data structure in the database is normalized at the level of the third normal form (3NF), with validation and redundancy reduction. and management duties designated in various categories of user permissions for accurate access to information as well as preventing data breaches and manipulation.

4.1.2 Culture mapping service

For the web mapping services that provide services for cultural tourism, the framework is a platform that can display a base map on Google Maps, which has two varieties of base maps to choose from covering a road map and a satellite. There is also a basic function for displaying Point of Interest (POI) locations, such as the function of displaying geographic coordinates and related information of ancient sites and cultural attractions, restaurants and resting stops, travel routes, and the search for information on places. This information are listed alphabetically at the beginning of an automatic search term (Autocomplete), navigating from one point to another (Directions Service), which shows distance and travel time, with link points that access virtual tour platforms and 3D models, etc. The next information??? is the list of available maps. There are 18 layers of information corresponding to a geodatabase. Tourists and general users can easily navigate by panning, zooming in and out, and selecting the items of interest in a dropdown bar on the left side of the web pages, or downloading through links to apply in geographic applications such as Quantum GIS (QGIS) for the purposes of further utilization. For less experienced developers, open-source code and flowcharts for numerous functionalities are available.

Figure 7 shows how it being used for assisting in managing the database along with the base map of Google Maps to facilitate travel or trip planning (Figure 8).

4.1.3 Virtual tour

In term of the virtual tour platform display, a series of equirectangular panoramic images of various archaeological sites and tourist sites are displayed. which can be rotated 360 degrees, together with hotspot icons for traveling or changing locations, displays descriptions and related brief information, while having the ability to interact with the user by sending a request to the database to load the image set data and display the items as per their of interest. In addition, virtual reality images can be displayed using a VR headset or a 3D glasses box, supporting displays on computers, tablets, and smartphones with both iOS and Android operating systems. Users are able to access it via two primary options namely: it can be linked via a hotspot on an online map or accessed via a direct menu item selection. It's very simple to use that is by just holding the mouse and moving it up, down, left, or right, or turning the smart device around and clicking a point of marker to show or hide its description. In a group of users with VR headsets or 3D glasses, the process is done by pressing the VR button and turning the users head in the desired direction. Virtual tours can be used as a publicity and learning medium by allowing users to experience a virtual environment before traveling on a trip. In the backend, there is a Pitch and Yaw location service function for the hotspot, a special open-source code program with the Pannellum library, and a flowchart of various (Figure 9).

4.1.4 3D model on WebGIS

On the 3D modeling platform, the model can be rendered with a description on the web page in accordance with the original model. It's very simple to use platform? by just pressing the scroll wheel of the mouse to zoom in or zoom out, and rotating 360 degrees by holding down the left mouse button and moving in the desired direction. The service system can be interacted through a menu bar list or marker point on an online map. On the 3D script file, there is a set of codes that transmit a request to the server to retrieve the database and showcase the list of models and related descriptions on the web page. Test results of showcasing 3D models on web pages with a personal computer demonstrate that the models can be displayed commonly and efficiently. However, there is a display limitation on smartphones and VR handsets whereby it can only display files of less than 100 MB. If the file size is less than 50 MB, it will be able to display faster. The effective file size is 10–50 MB, with a latency of 10–20 seconds depending on the cellular signal's performance speed and the RAM onboard the smartphone. Files larger than 100MB takes 3-5 minutes or fail to display.

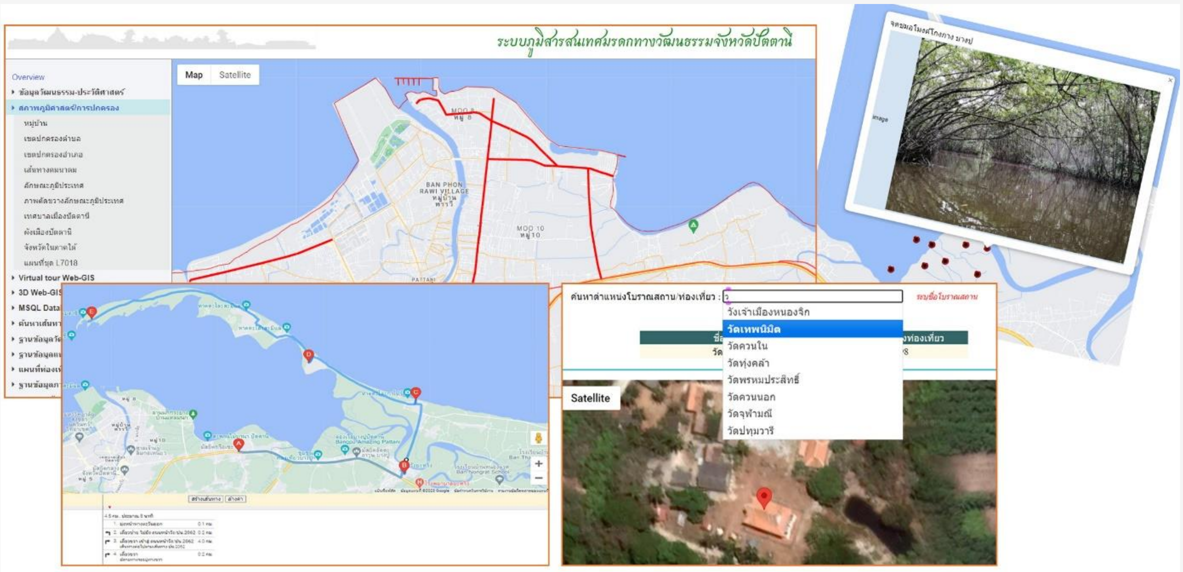

Figure 8: Online mapping platform

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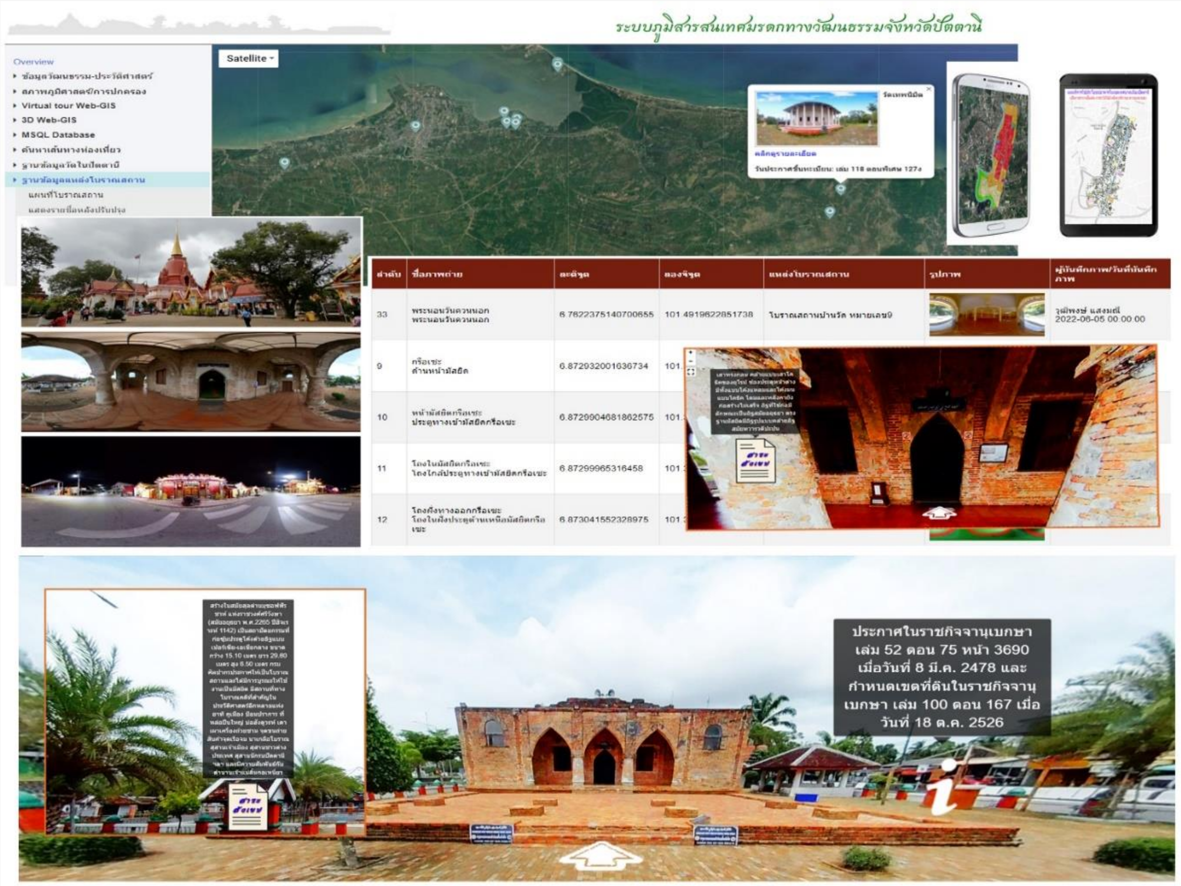

Figure 9: Virtual tour platform

This limitation in file size per display on smart devices is a result of the capabilities of the A-Frame library. Troubleshooting before executing any tasks include these elements, namely, checking the console on the A-Frame library for errors. The console will inform the user if the model requires additional missing files. If the model is distorted or missing, then the user has to use Blender to discover and re-texture it until satisfactory results are achieved, followed by resuming the whole process.

4.2 Satisfaction Assessment

User satisfaction is the requirement for success in the development of this framework and considered as one of the parameters that will contribute to more efficient implementation and improvements. The results of the satisfaction assessment of the 30 samples who used the system were found to have an average satisfaction level of 4.185 or very satisfied. The satisfaction level is classified by the following attributes: 1) Display function ($\bar{X}$ = 4.19, S.D. = 0.63), 2) Facilities and service ($\bar{X}$ = 4.18, S.D. = 0.60) Between the groups of travelers and general users and the groups of academicians/staff according to the means of *T-test independency*, it was found that T-critical (2.048) > T-value (0.546) which inferred that the opinions of the two groups were not significantly different. With Significance value of *df* = 28 as detailed in the following topics of interest.

1) In terms of display function, it was found that the sample had the highest level of satisfaction in terms of the database management system, the online map displayed with the database, and the virtual tour and virtual reality service system. There was a high level of satisfaction with the level of difficulty in using the system namely, ease of accessing the system, and the authentication system is easy, convenient, and correct as well as a moderate level of contentment on the issue of the 3D model information service system.

2) With regards to service and facilities, it was found that the sample had the highest level of satisfaction with the item. The following were the findings, namely, The navigation tools in the program are easy to use and not complicated; able to select items or locations from the first page correctly while being used, ability to change to another place correctly, can return to the first page accurately while using an

online map, useful in facilitating travel; the language is easy, precise and concise to understand; the information presented is interesting; and the presentation of the virtual reality tours in the attractions is appropriate. There was a high level of satisfaction with the item's appropriate graphical user interface (GUI). Moderate satisfaction was found related to items using VR headsets or 3D glasses which is convenient and easy to install, as well as quick and easy in installing its functionality.

5. Conclusions

5.1 Framework Performance and Constraints

This Web GIS design and development emphasizes a low-cost with reasonably performance framework that is suitable for programming in an open-source code module for a web mapping service system (WMS). In addition, it offers a flexible, low-cost system architecture approach with simple open-source code that incorporate together a library of prominent community developers to address existing rendering problems uniquely and separately from each other. This framework, thus provides a medium for integrating collaborative processes and visual hyperlinks between online mapping technologies, virtual reality tours, and 3D models to work together on web pages. Beginner developers, local authorities, and small enterprises can simply implement this and/or deploy it to each platform according to their availability, needs and budget. In the system, there are functions to facilitate and disseminate information related to cultural tourism content in Pattani Province, which can be applied to any works in a similar manner.

The results of the sample interviews have beneficial comments and suggestions that are essential to the framework, including its novelty in term of innovation that creates historical and cultural sites in the form of accessible digital documents. By using a map as a navigation component to know and access the location and a series of visual tours, virtual reality allows users to view and move, adding a fresh and thrilling experience and creating a feel as though the user is actually in that situation. However, in platform virtual reality (VR), the use of platforms is still limited to the following two functions specifically mentioned as follows: VR requires a headset, which is a significant obstacle, including portability. There are still inconvenient, expensive, and convoluted connection methods, and most of the samples did not have VR headsets to use. The VR headgear is only used by relevant officials and government agencies with budget capabilities. Comments received mentioned that the virtual tour travel media is sufficient and can be accessed and learned. Due to the above reasons, general users may not be able to access VR. In addition, there is the limitation of a very large model file size. This is normal for models using photogrammetry. If the file size cannot be reduced, it may impede the display. There are also issues related to the capacity or potential of the processor on the smartphone in the sample. The speed of the 5G phone infrastructure is also another concern which has not yet encompassed the entire study area.

5.2 System Capabilities and Future Development

The result of the development of this framework, it can be seen that online mapping and virtual tour platforms are efficient and practicable at a low cost, but 3D models are limited in rendering due to the large file size. In addition, the sample of users who have tried using VR devices commented that virtual reality tours can be interactive and readily accessible via smartphones or computers and are sufficient to meet their requirements. Moreover, a group of academicians and concerned officials have held the opinion that the way the itineraries are constructed in virtual reality tours should not be one-size-fits-all but there should be many types according to the age and individual characteristics as well as distinctive enough according to the type of content, desirability in having a character or 3D model as an informative guide or offer various advice, and able to run quicker on smartphone devices.

Future developments will define a framework concentrating on the following topics: a) Improving the techniques of open-source code to develop the platform into a web cloud and training program in the front end refers to the markers in the virtual tour that will help one realize reverence for the place and the relics. The source coding determines the active screen size appropriate for various age groups. Whereas in the back end, we will be able to update the information, including increasing the number of relevant locations or attractions, and devising various techniques used to create 3D models in order to have appropriate file sizes, precision, and rapid display. b) It is worth noting here that working with social science and humanities tourism developers to produce media that tell stories that are uplifting, socially responsible, and engaging while traveling is an effort that can be given more attention in the future to the benefit of using this technology.

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