

Development of virtual tour reality using 360-degree panoramic images and Leaflet JavaScript

Lanto Ningrayati Amali, Muhammad Rifai Katili, Alif Perdana Sugeha

Department of Informatics Engineering, Faculty of Engineering, Universitas Negeri Gorontalo, Gorontalo, Indonesia

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ABSTRACT

This paper describes virtual reality (VR) development using a 360-degree panoramic and Leaflet JavaScript (Leaflet JS) to introduce campus buildings in real-time. The campus building of Universitas Negeri Gorontalo (UNG) in Bone Bolango Regency was chosen as a case study. It allows users to navigate and listen to background sound and narration, open the site map interactively, and read brief information about each location. Each panorama contains hotspots that allow users to explore further. All images are combined using a photo-stitching technique to produce a panoramic image. The research method used is the multimedia development life cycle (MDLC), which consists of six stages: concept, design, material collection, assembly, testing, and distribution. Based on the system usability scale (SUS) test, the virtual tour reality website application received feedback from users regarding its usability, satisfaction, and effectiveness, and it is interesting to use this application. The results show that the website application can visualize the campus building environment with various layers of information and can create a very realistic and detailed representation of the campus environment.

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Corresponding Author:

Muhammad Rifai Katili

Department of Informatics Engineering, Faculty of Engineering, Universitas Negeri Gorontalo

Prof. Dr. Ing. B. J. Habibie, Gorontalo, Indonesia

Email: mrifaikatili@ung.ac.id

1. INTRODUCTION

Information technology (IT) has significantly impacted humans in almost every area of life, where technological developments have brought unprecedented digital transformation and unparalleled educational opportunities [1]. Digital transformation refers to the general changes experienced by institutions and society due to new digital technologies [2]. Meanwhile, technology can be innovated at the organizational level by developing strategies that encompass the implications of digital transformation and drive better operational performance [3].

In the last decade, tourism and education have faced challenges in digital transformation [4]–[6]. Universitas Negeri Gorontalo (UNG), a higher education center in Gorontalo, accepts students annually from Gorontalo and all over Indonesia. Information media plays a vital role in attracting prospective students as a means of promotion, where there needs to be more information about UNG to the public. UNG has information media in the form of brochures and websites. The current website provides news, images, and video content in text and static images. This needs to be improved for users, as they require more knowledge of UNG's facilities and forms.

Digital technology can help people get information more easily. This digital technology packaging includes information and promotional media in 3D (three-dimensional) multimedia, virtual tours, and virtual

reality (VR). This artificial intelligence produces dynamic, three-dimensional objects that simulate the built environment, where users can view the site holistically [7]–[10]. Virtual tour applications as information media are more efficient and exciting because virtual tours are more supportive than existing print and online media with limited information [11], [12].

Rapid technological development has led to several innovations in virtual tour technology. Some studies state that 360-degree virtual tours can make it easier for potential visitors and users to find facilities and shapes that match reality [13]–[15]. These virtual tours allow users to explore selected locations using images that can be navigated easily. For example, Northern Michigan University (NMU) has provided a virtual campus tour on its interactive website that allows users to 'walk around' the campus [13], as well as a virtual tour conducted by Cuba's National School of Art as an introduction to the site for users to understand how the site was built [9]. This technology allows users to explore campuses or sites without walking directly through them. According to [16], his technology will enable users to explore a location and get information about it so that they seem to be in that location.

Some of the research above shows that virtual tour technology focuses more on VR and information modeling (IM) approaches. This method is more efficient if the building or area to be documented cannot be captured using 2D methods and 3D models are unsuitable for project needs, such as conservation projects. Other research is limited to virtual tour technology without using different technologies, such as interactive maps that can open up space for ordinary users to understand the map more efficiently and a relatively attractive and supportive interface to be displayed on mobile and desktop platforms [17]. This indicates that the information provided is limited to spatial data. Therefore, with the development of virtual tours, universities should expand their information beyond these boundaries.

Virtual tours simulate a location based on reality using 360-degree panoramic photos (reality photography) [18]–[20]. The resulting place, such that the site resembles the virtual world, is a combination (stitching) of images and objects [21], [22]. VR photography is processed to allow users to interact directly with virtual places. This VR photography, also called immersive photography or 360° panoramic photography, shows a location continuously, smoothly, and seamlessly at a 360-degree viewing angle in the horizontal and vertical directions [23]. Virtual tours provide an overview of places that correspond to the original tour.

Using the Leaflet JavaScript (Leaflet JS) library and audio as information media for the campus area helps to build web-based interactive map applications. Leaflet JS supports various platforms, such as mobile and desktop. In addition to Leaflet OpenLayer and Google Maps API, it is also a JavaScript library for building map applications that are very popular today [24], [25]. Using leaflet JavaScript, developers with no GIS background can easily display web-based interactive maps on a server. The leaflet can display layers from GeoJSON files, organize them, and create interactive layers such as text markers that show pop-up information when clicked. Leaflet JS is a JavaScript library for developing open-source maps [26].

This research aims to develop a Virtual Tour Reality website application for the UNG campus as information media based on 360-degree panoramic images and Leaflet JS. In contrast to previous research, virtual tour reality in this study uses 3D engineering results. The creation uses the 3D Max application, leaflet library, JavaScript, and audio. As a result, the virtual tour can be used to explore campus facilities and display 3D objects on the campus area map, both on mobile and desktop platforms. This can make it easier for potential visitors to find the facilities and location of the UNG campus. With virtual tour reality combined with an interactive map on the website, users can experience the digital environment in real-time, allowing them to explore the campus environment as if it existed. This can help prospective students, visitors, faculty, and staff locate resources and buildings and evaluate the tour at their own pace without needing assistance.

2. METHOD

The research location of the UNG campus is in Bone Bolango Regency, Gorontalo Province. This study used the multimedia development life cycle (MDLC) method to develop a Virtual Tour Reality website application that combines images, sound, video, animation, and other media [27]. The research stage comprises concept, design, material collection, assembly, testing, and distribution as shown in Figure 1.

A. Concept

The development stage begins with determining the purpose of making the application, target users, and virtual tour material that will be displayed. In this research, the purpose of making applications is to utilize 360-degree panoramic virtual tour technology as a medium of campus area information for people in Gorontalo and surrounding areas and in Indonesia. Therefore, the virtual tour material is in the form of 360-degree panoramic images and information about the names of UNG campuses.

B. Design

The next stage of the MDLC process is design. At this stage, detailed website design specifications and 360-degree panoramic virtual tour photos are made using unified modeling language (UML) diagrams

through use case diagrams, activity diagrams, sequence diagrams, class diagrams, database designs, and interface designs. Storyboard describes the description of each scene, lists all multimedia objects and links to other scenes, and flowchart to show the flow from one scene to another.

C. Material collecting

At this stage, materials were collected to fulfill the needs, such as preparing a camera, 360-degree tripod, or Panoramic Head. In addition, 360-degree panoramic images were collected from several locations, including essential buildings/neighborhoods/places or landmark information for users. Building models visualized using virtual tours were obtained from literature studies and various sources such as libraries or websites.

D. Assembly

At this stage, all objects in the form of panoramic images were taken for virtual tours and website creation based on use cases, activity diagrams, sequence diagrams, class diagrams, and interface designs. The captured images were stitched and edited using auxiliary software, such as Adobe Photoshop, Panoweaver, Pannelum plugin, and a code editor application using Visual Studio code. In other words, the creation of the application was based on the storyboard, flowchart, and navigation structure in the design stage.

E. Testing

After completing the build stage, black-box and white-box testing [28] of the built application is carried out. This testing is done by running the application/program and observing errors. This is important to avoid mistakes in the development of applications.

F. Distribution

The application distribution stage is preceded by a system evaluation of users using the system usability scale (SUS) [29]-[31]. This ensures user acceptance of the built application and improves the developed product. The results of this evaluation can be used as input for the next stage of the product concept. Next, the application is packaged according to the media distributed. In this case, the virtual tour is published on the website as a promotional medium.

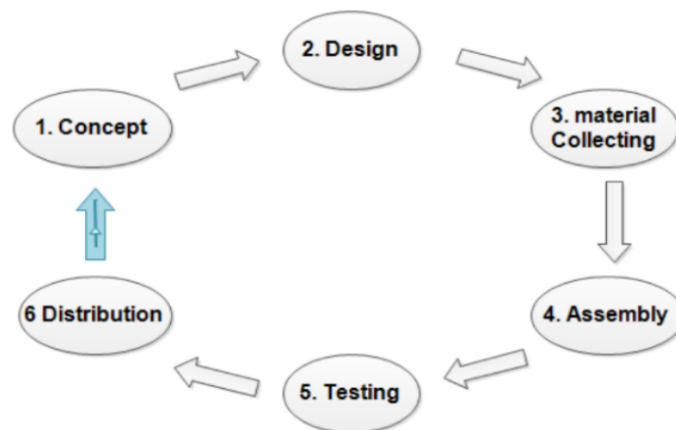


Figure 1. Research phases

3. RESULTS AND DISCUSSION

This research was conducted to develop a VR software that can display the Universitas Negeri Gorontalo campus environment in real time. The concept of developing virtual tour reality is to produce media that can display information about locations in the UNG campus environment in 360-degree panoramic images. The final result produced is a 360-degree panoramic virtual tour reality website with target users being people in the Gorontalo area, Indonesia, and abroad in general.

The virtual tour reality development concept results in media that display information about environmental locations on the UNG campus in 360-degree panoramic images. The final result is a 360-degree panoramic virtual tour reality website, with target users being people in the Gorontalo area in particular and in Indonesia in general. The material in this virtual tour was in the form of 360-degree panoramic images and information on the names of the locations on the UNG campus.

The design is carried out so that the needs of the software creation process, such as the software and interfaces, can be prepared appropriately. To design this application, UML diagrams (use case, activity, sequence, and class diagrams), a database, and interface design were used. Figure 2 shows a use-case diagram of the differences between the users and administrators.

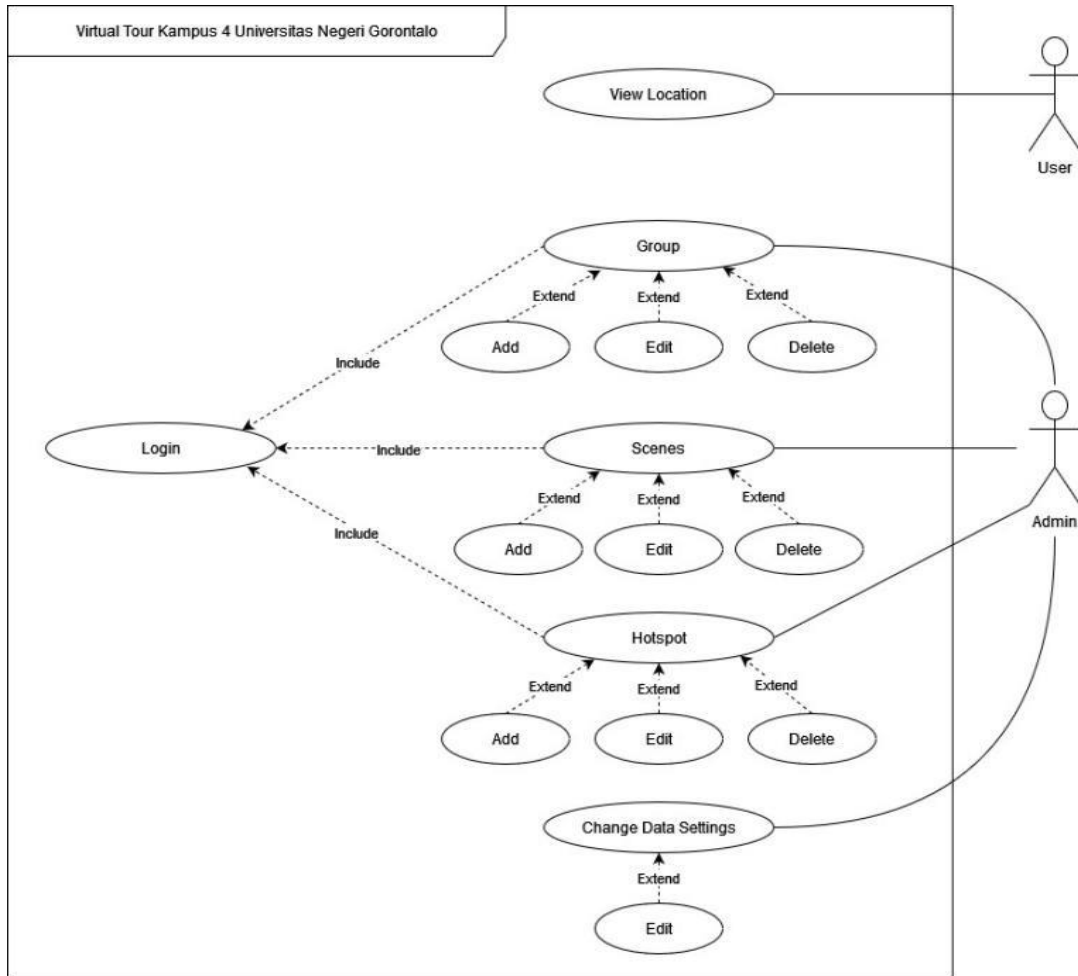


Figure 2. Use case diagram of the virtual tour

In the material gathering stage, images are collected from several locations included in the virtual tour by considering the server capacity because the panoramic image data for each photo is very large. The shooting point must be determined before getting the panoramic image. This determination affects the viewing angle of the panoramic photo to be created, as shown in the example in Figure 3, which can be affected by several factors, such as:

- The location must contain information from all angles, including the front, side, and rear views. As far as possible, the images were captured from the center of the location.
- There are points available to create hotspots. Ideally, a virtual tour should be a collection of panoramic images connected to other panoramic photos; therefore, hotspots should be installed.



Figure 3. Illustration of panoramic image pointing

Based on the use case design, activity diagram, sequence diagram, class diagram, and interface design that has been designed, all objects or materials are combined in one website. This assembly stage begins with stitching by combining the images taken and turning them into a 360-degree panoramic photo. The panoramic image created is a spherical panorama, which allows 360-degree observation, thus providing a view of the entire environment at once. The stitching result is shown in Figure 4.



Figure 4. Output panorama image in the form of spherical panorama

Furthermore, the photo was converted into a panoramic cube using the Panoweaver application. A cube panorama is a panoramic image that forms a cube-like pattern consisting of six square photos that resemble the sides of a cube. The advantage of this type of panorama is that it is easier to retouch the image during editing. The conversion process for the Panoweaver application is illustrated in Figure 5.



Figure 5. Output panorama image in cubic panorama form

The stitched image still left traces of the tripod, so these had to be removed using the Photo Editing process. The panoramic image was edited using the Healing Brush Tool. Panoramic image editing is done with precision to produce natural images, such as the condition of the land and plains around the location. The panoramic image that is currently managed is still a panoramic cube image. Therefore, it must be converted to a panorama that supports spherical panoramas. Panoweaver software can convert panoramic cubes into spherical cubes or vice versa.

The color correction process helps to equalize the image's color so that the color change is not too different from other images. After the color correction process, face blurring is performed on images that contain people. This is done to ensure the privacy of the person being photographed. The 360-degree panoramic image is made from several photos combined, each of which is large, so the panoramic image needs to be compressed to save space on the server and speed up the image loading process while on the website. As for the result, the Assembly Website VR tour is made as similar as possible to the design model. As seen in Figures 6 and 7, the website's home page is the display that first appears when users access the virtual tour website. The reality tour website features a location sidebar where the name can be clicked and

instantly displays a 360-degree panoramic image of the user-selected location. The hotspot button connects the scene to the 360-degree panoramic view. When the pointer is pointed at the hotspot button, the name of the destination location will be displayed if the user uses it. The zoom-in feature is used when the user wants to enlarge the image and bring the view closer. The Full-Screen feature turns the panoramic photo the user is viewing into a full screen. The full-screen map and marking area features vary the map or maps across layers.

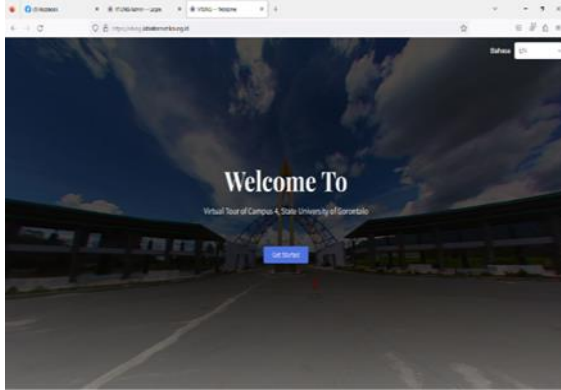


Figure 6. Website home page



Figure 7. Display when pressing the start button

After the assembly stage is completed, black-box and white-box testing of the assembly results is carried out to evaluate the quality and suitability of the VR tour website. The test results are made to prove and show that the development objectives have developed the project and can meet user needs. The white-box test results were obtained by testing one of the source codes in the system created, as shown in Table 1.

Table 1. The results of white-box testing

Node	Program code
1	private function generateScenePannelum (\$scenes){
2	\$ scenesPannelum = [];
3	foreach (\$scenes as \$scene){
4	\$hotspots = [];
5	foreach (\$scene->hotspots as \$hotspot){
6	\$hotspots[] = ["pitch" => (float) \$hotspot->pitch, "yaw" => (float) \$hotspot->yaw, "type" => 'scene', "text" => \$hotspot->text, "sceneId" => \$hotspot->sceneTo - >slug,]; }
7	
8	\$ scenesPannelum [\$scene->slug] = ["title" => \$scene->title, "hfov" => \$scene->hfov , "pitch" => \$scene->pitch, "yaw" => (float) \$scene->yaw, "type" => (float) \$scene->type, "panorama" => Storage: url (\$scene->image), 'hotSpots' => \$hotspots, 'long' => \$scene->long, 'lat' => \$scene->lat , 'sound' => \$scene->sound! = null? asset('storage/' . \$scene->sound) : null ,]; }
9	
10	\$ scenesPannelum = json_encode (\$ scenesPannelum); return \$ scenesPannelum;
11	}

This shows that the test results serve to test the application's main functions and are as expected. Figure 8 shows the flow chart from the white-box testing of the request data process file. Table 2 and Figure 8 are followed by a cyclomatic complexity measurement, a quantitative measure of the logical complexity of a program, as shown in Table 3. The result of this measurement is to determine whether a program is simple or complex based on the logic applied to the program.

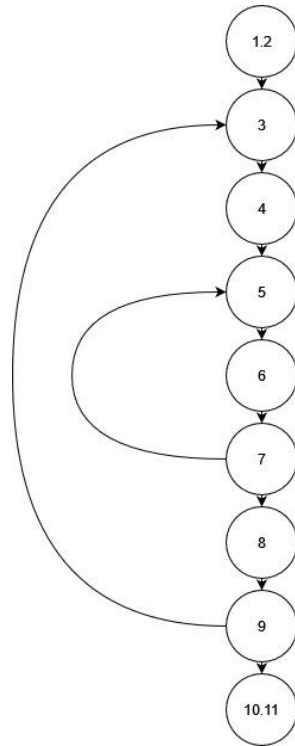


Figure 8. The flow graph

Table 2. Independent path flow graph notation

Basic flow	Independent path
Path 1	1-2-3-9-10-11
Path 2	1-2-3-4-5-6-7-8-9-3-10-11
Path 3	1-2-3-4-5-6-7-5-8-9-10-11

Table 3. Cyclomatic complexity

Basic flow	Independent path
$V(G)=E-N+2$	E=the number of arcs in the flow graph is 10
=10-9+2	N=Number of vertices in flow graph 9
=3	

After completing the testing phase and ensuring all functions run correctly, an evaluation is carried out to ensure the quality of the application using the SUS approach. This is important to measure the effectiveness, efficiency, and user satisfaction in the application's context. Based on measurements using SUS, a score of 79 was obtained as shown in Figure 9, so the score is included in the adjective ratings good category with a grade scale of B. This means that usability based on this data gets an acceptable assessment. The results of this measurement show the evaluation of product usability from the aspects of effectiveness, efficiency, and satisfaction subjectively felt by users.

The application of VR technology [10] using 360-degree panoramic images and Leaflet JS in this research is systematically used to make the software developed can provide interactive experiences to users by creating a more immersive view and approaching physical experience. This shows innovation in the field of IT and can be an example of using the latest technology to develop educational and tourism content. The hotspot integration and interactive map features can provide users with an interactive and immersive

experience. They can explore various locations, see details from all angles, and deeply feel the campus's atmosphere. This allows users to connect between one location and another, increasing the depth of the user experience in exploring the campus area.

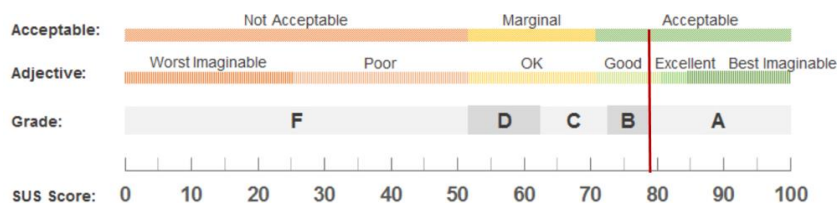


Figure 9. Graph of SUS score results

However, some things can be a challenge. The virtual tour reality software only partially represents the physical experience of visiting the campus. The virtual medium may only partially convey atmosphere, noise, and direct interaction with people. The information included in the virtual tour is also limited to location names and panoramic images. Additional details, such as in-depth descriptions of each location or specific information, may need to be sufficient for some users seeking more information. In addition, the user experience browsing the virtual tour is highly dependent on the internet connection. Content maintenance, such as the availability and accuracy of the virtual tour content, also requires regular periodic content maintenance and updates, which can be due to changes in the campus, such as new construction or location name changes.

Ultimately, this kind of research can continue to be improved by meeting these challenges and improving the quality and accessibility of virtual tour reality. This campus virtual tour reality software can be used as an educational promotion tool. Prospective students and parents can access and explore the UNG campus from anywhere, gaining in-depth insight into the facilities, environment, and other essential locations, which can be a deciding factor in educational decision-making. In addition to educational purposes, this virtual tour can also be a tourism promotion tool. Furthermore, the virtual tour website is designed to be accessible to anyone worldwide with an internet connection. This allows the UNG campus to be recognized by the international community and can be an attraction for prospective international students and collaborators. Further development could involve expanding features like voice-guided virtual tours, integrating e-learning platforms, or using augmented reality technology for more contextualized learning simulations.

4. CONCLUSION

Communication media virtual tour reality based on 360-degree panoramic images and Leaflet JS developed can provide exciting and realistic information about the UNG campus. The virtual tour reality applications are designed and built to convey factual information as similar as possible to the original tour. The results of black box and white box testing on the quality and suitability of VR tours and feasibility testing from user perceptions based on SUS score show that virtual tour reality software can meet user needs. This makes virtual tour reality software a promotional medium for local and international communities. Users, such as prospective students and parents, can access and explore the UNG campus from anywhere, gaining in-depth insight into facilities, neighborhoods, and other essential locations, which can determine the education decision-making process.

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BIOGRAPHIES OF AUTHORS






Lanto Ningrayati Amali    received her Doctoral Degree in Information Technology from the Universiti Utara Malaysia in 2015. Her research interests include IT governance, system planning, and management of information systems. She has published and presented her research nationally and internationally in IT Governance, Information Systems, and System planning. She is currently a lecturer in the Faculty of Engineering at the Department of Informatics Engineering, Universitas Negeri Gorontalo in Indonesia. She can be contacted at email: ningrayati_amali@ung.ac.id.



Muhammad Rifai Katili    received his Doctoral Degree in Information Technology from the Universiti Utara Malaysia in 2018. He is a faculty member at the Informatics Engineering Department, Faculty of Engineering, Universitas Negeri Gorontalo in Indonesia. His research interests include knowledge management, information systems, and IT governance. He can be contacted at email: mrifaikatili@ung.ac.id.



Alif Perdana Sugeha    is an undergraduate student of Information Systems in the Faculty of Engineering at the Department of Informatics Engineering, Universitas Negeri Gorontalo in Indonesia. Currently, he has completed his study program. He can be contacted at email: sugeha.perdana@gmail.com.