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PAPER

Exploring Campus through Web-Based Immersive Adventures Using Virtual Reality Photography: A Low-Cost Virtual Tour Experience

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ABSTRACT

This study aims to assess the incorporation of virtual reality (VR) photography into the web-based immersive application “virtual interactive campus tour (VICT).” This application offers users an immersive experience, allowing them to virtually explore university campuses and access information about the facilities and services available. The VICT application offers a cost-effective, attractive, and sustainable alternative for universities to display their resources and interact with potential students. Through black box testing, we conducted user acceptance testing (UAT) and functionality testing, confirming the application’s readiness for deployment and its capability to meet institutional and end-user requirements. This study also examined the potential for universities to use VR to meet the expectations of prospective students. The application is compatible with both desktop and mobile devices. The results indicated that the overall average validity score was 0.88, suggesting that the measure is valid. The validation results were thoroughly tested and reliable. This study emphasizes the potential of immersive web-based tours in higher education and aims to bridge the divide between virtual exploration and physical visits. By offering an immersive virtual campus experience, this innovative tool has the potential to revolutionize university marketing strategies, increase student engagement, and transform campus visit approaches.

KEYWORDS

virtual reality (VR), virtual tour, educational technology, web-mobile application

1 INTRODUCTION

Recent rapid advancements in digital technologies have led to significant changes in various aspects of life and sectors [1]. The adoption of innovative technologies has led to changes in daily routines, habits, and overall lifestyles [2]. The global COVID-19 pandemic has accelerated the digital transformation process [3]. This transformation

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has led to several emerging technology trends that have attracted significant interest (see Figure 1). These trends include blockchain, non-fungible tokens (NFTs), metaverse, gamification, mobile learning, microlearning, augmented reality (AR), virtual reality (VR), mixed reality (MR), extended reality (XR), Web 3.0, the Internet of Things (IoT), quantum computing, super apps, robotics, and artificial intelligence (AI) [4–10].

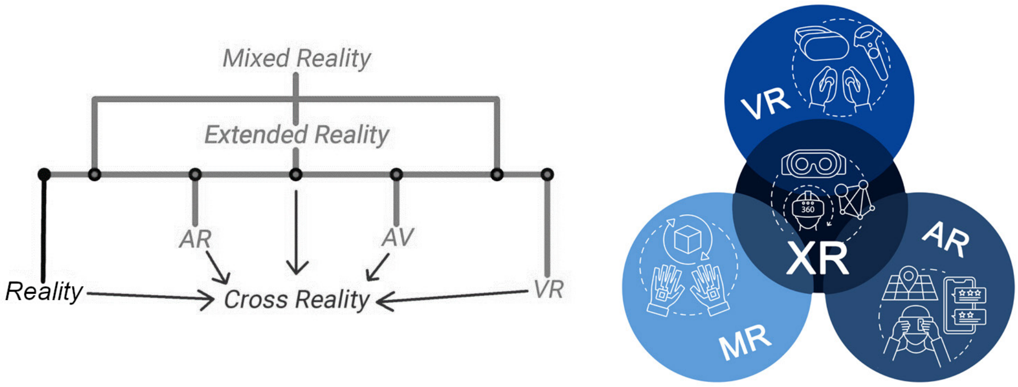

Fig. 1. Emerging technologies (AR/MR/VR/XR)

These groundbreaking technologies have the potential to revolutionize trends and lifestyles. Digital innovations, such as artificial intelligence and blockchains, have had a significant impact on how we interact, learn, work, and entertain ourselves [11], [12]. It is essential to distinguish between these technologies, especially for immersive technologies such as VR, AR, MR, and XR [13]. While AR overlays digital elements onto the real world [14], MR encompasses immersive technologies that merge virtual and real-world elements to create a hybrid experience [15]. VR fully immerses users in a digital environment, allowing direct interaction with its components [11]. XR is an umbrella term encompassing AR, VR, and MR, aiming to merge or simulate the digital and physical worlds with interactive capabilities (Figure 2).

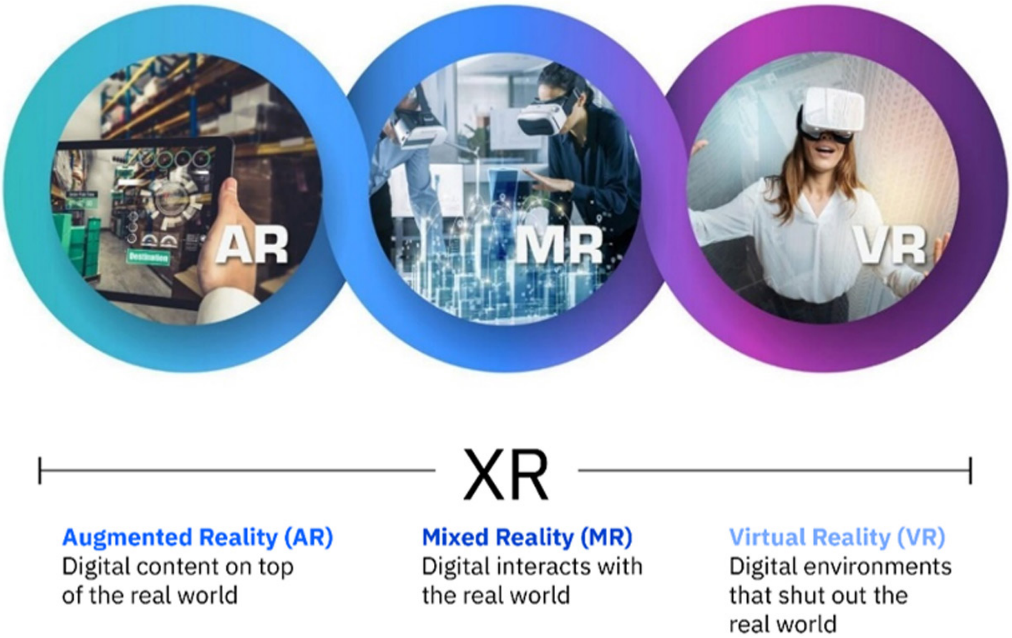

Fig. 2. How AR/MR/VR/XR are different from each other

The Faculty of Engineering at Universitas Negeri Padang (FT UNP) is highly sought after by prospective students, especially the electronics engineering department, which offers a variety of study programs. To support these programs, adequate information facilities are essential. The university has made various efforts to communicate information about its facilities, services, and other relevant details to the public, particularly prospective new students.

The current promotional efforts include websites and brochures. However, these media primarily consist of static images and one-way videos, which do not offer an immersive technological experience for users. Immersive technology can blur the boundaries between the physical world and the digital or simulated world, enabling users to engage with an environment that closely mirrors reality [16], [17]. Images are a highly preferred means of conveying information because they are considered the most reliable form of depicting real-life situations.

One of the emerging forms of visual media today is 360-degree panorama images. By combining the panorama method with VR technology, it is possible to develop VR that offers a 360-degree visual representation using smartphones and the Internet. The VR tour that will be created will also include a voice guide to provide information and educate prospective students and parents about the buildings and facilities being visited.

Meanwhile, according to data from the Indonesia Internet Service Providers Association (APJII), Internet penetration in Indonesia is at 73.7 percent of the total population, which equates to approximately 202.7 million users. Moreover, the utilization of digital services in Indonesia has increased by around 37% during the pandemic. Considering these statistics, the development of VR tours aligns well with this trend and is poised to have a significant and positive impact on new prospective students and parents when making their final decisions about which university and study program to choose.

In addition to serving as digital information and educational media, VR tours can also function as a virtual visitation support application. Furthermore, virtual tours provide digital freedom of movement without limitations on time and location, as well as without the need for extra resources and expenses. They supported unrestricted visits with no limits on the number of visitors. This means that there is no pressure regarding overcrowding, crowds, or noise, offering a new experience for students, prospective students, parents, or anyone else to visit anytime and anywhere in a more efficient, effective, and enjoyable manner.

This advanced study focused on creating, testing, and distributing a virtual tour. The concept, design, and material collection aspects have been discussed in previous research [18]. This virtual tour concludes with a web-based application that can be accessed on mobile devices and desktop computers. VICT enables users to explore outdoor and indoor areas by providing an audible guide with essential information, services, facilities, and location-specific details. The research analyzed the final outcomes, testing, and deployment of the application.

To guide our investigation, we formulated the following research question:

RQ1: How does the web-based virtual campus tour application (VICT) enhance the exploration of outdoor and indoor areas by providing an audible guide with essential information, services, facilities, and location-specific details for prospective students and visitors?

RQ2: What is the impact of using 360-degree panoramic image technology in the development of VICT in terms of its cost-effectiveness in image production and its ability to create realistic and immersive visual effects? How do the results of black box testing and UAT from the user's perspective contribute to the accessibility of campus environments and the development of virtual tour applications across various domains?

2 LITERATURE REVIEW

2.1 AR, VR, MR, and XR

Virtual reality has been widely applied across various domains, and tourism is no exception [19]. Virtual tours are a common application of VR in the tourism sector [20], [21]. These virtual tours aim to replicate real-world locations, often comprising static videos, images, and 3D visualizations [22]. To enhance the immersive experience, additional multimedia elements, such as narration, text, sound effects, and music, are often integrated. The technology used for capturing virtual tours, including omnidirectional cameras and image-stitching techniques, has expanded the applications of virtual tours to universities, real estate, and the hospitality industry. This offers an online exploration of various environments [16].

Modern virtual tours, known for their accessibility and high quality, often include integrated maps or floor plans to help users navigate. For commercial purposes, virtual tours must be easily accessible, making web-based virtual tours a practical solution. Moreover, a truly engaging and informative virtual tour goes beyond a simple sequence of panoramic images. By integrating diverse content, such as video, text, and interactive 360-degree panoramic photos, a more immersive web-based experience can be created.

Recognizing the potential of this technology, companies like Google Maps have integrated it into their operations to create virtual representations of real environments using millions of panoramic images. These panoramic images offer a nearly 360-degree field of view, a technique often referred to as VR photography (VRP). VRP facilitates the interactive display of panoramic images, including flat panoramas, 360-degree circles, and spherical viewpoints [23].

2.2 Virtual reality

Virtual reality is an advanced technology that enables users to interact in a computer-generated, simulated environment [24]. VR technology enables users to immerse themselves in a virtual space, allowing them to freely explore, learn, and observe objects in a believable and tangible manner [25]. This immersive experience is achieved by rapidly processing and rendering the virtual environment in response to user movements, creating an irresistible feeling of being present. The poignant 2020 documentary "Meeting You" depicts a mother's emotional VR reunion with her deceased son, highlighting the emotive potential of VR [26–28].

Virtual reality photography is a technique that enables interactive viewing of panoramic photos with a wide field of view. Typically, the VRP captures a 360-degree angle, encompassing a full spherical view (see Figure 3). It includes several interactive visual presentations, such as panoramas and video objects. Panoramas are images that provide a wide-angle perspective, creating the sensation of being immersed in a captured scene. Computer processing enables the enhancement of VRP images. Users can then view the resulting VR panoramas through interactive interfaces, which allow them to rotate their viewpoint horizontally and vertically, simulating a real-world experience. A virtual tour is a simulated representation of a place or location that includes multimedia elements such as videos, photographs, background music, narration, and text. These components are collectively designed to provide users with an engaging and informative experience [29].

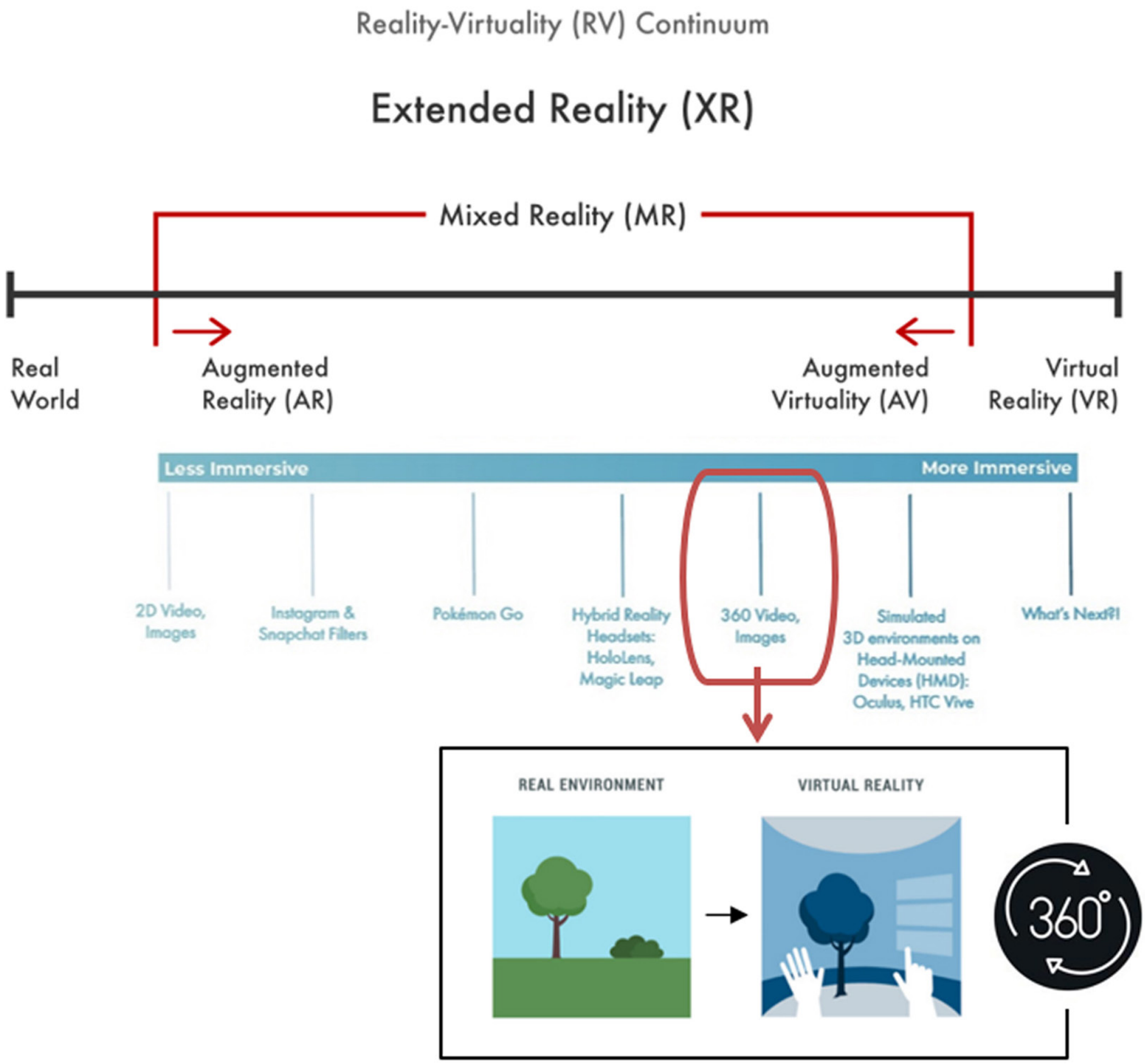

Fig. 3. Reality-virtuality continuum (360 panoramic image illustration)

2.3 Panorama

The panorama depicts a vast, unobstructed, natural landscape. An English painter, Robert Barker, coined the term "panorama" in 1787 to describe his circular works. Its origins can be traced to the Greek words "pan" (meaning "all") and "horama" (meaning "view"). M. Garrela, an Englishman, patented a camera in 1857 that could capture a complete 360-degree panorama [30] by rotating about its axis. This groundbreaking camera was the first to incorporate a clock-controlled fan mechanism [31]. Currently, there are a wide variety of panoramic cameras available on the market. With modern technology, people can easily view stunning panoramic views of global locations without being there physically [21]. In contrast to traditional panoramic images with limited viewing angles, we convert 360-degree panoramic photos into a virtual format, providing a comprehensive perspective [31].

2.4 Web-based application

Web-based applications are compatible with a variety of hardware devices, including desktop computers and mobile devices. Commonly known as "web applications," they are accessed through a web browser over an intranet or the internet [32]. Users interact with these applications using the browser as a client, which serves as an intermediary between the underlying system and the functions performed by the user within the application. This client-server model facilitates smooth communication and efficient task execution. Users can access web-based applications from different devices and locations, thanks to the widespread use of web browsers, which offer a versatile solution.

2.5 Information technology

Information technology (IT) encompasses the utilization, development, and administration of computer systems, software, networks, and electronic data to facilitate the storage, processing, transmission, and retrieval of information. It plays a crucial role in supporting a variety of organizational and societal activities. Immersive technology is a transformative tool that blurs the boundaries between the physical world, the digital realm, and simulated environments, enabling users to experience an environment similar to the real world [33]. Images have emerged as one of the most popular and reliable means of conveying information in modern society. In the field of information media, there is a growing trend towards the development of 360-degree panoramic images. Combining panoramic techniques with VR technology enables the creation of VR experiences with a 360-degree visual perspective, which can be accessed via smartphones and the Internet.

3 METHODOLOGY

This research and development (R&D) study aims to create innovative, practical, effective, and valid applications. Moreover, this study employed a multimedia development life cycle (MDLC) approach [34]. The process begins at the conceptual stage and concludes at the distribution stage. However, this study focused solely on the assembly, testing, and distribution stages, building on previous research [18]. A more detailed explanation is provided in Figure 4.

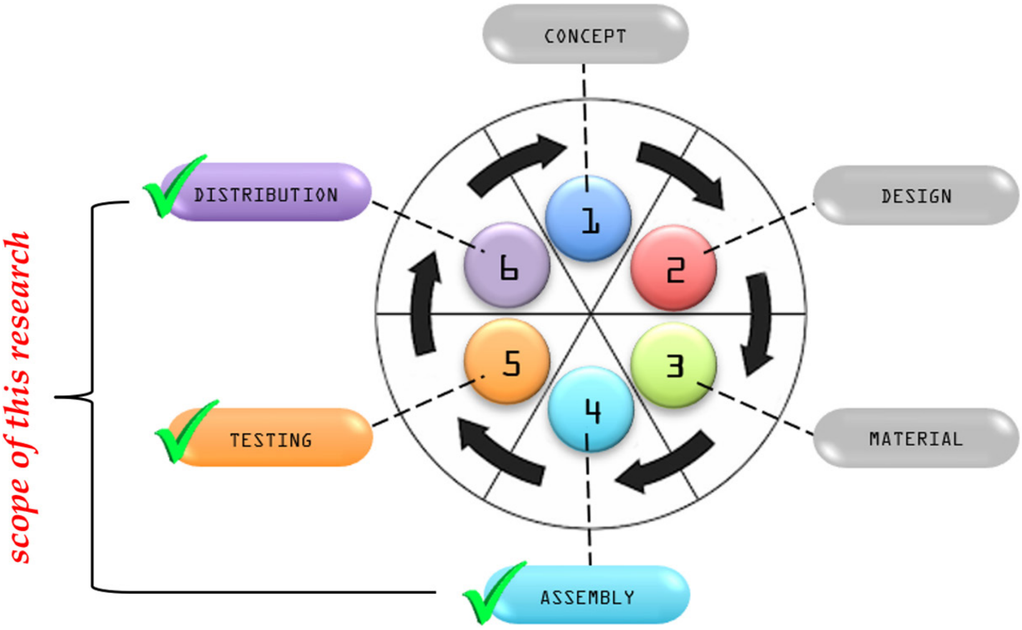

Fig. 4. Multimedia development life cycle

The end users assessed the final research results to determine their effectiveness and collect user feedback. This evaluation considered two different perspectives.

1. **Developer's perspective.** Utilizing functional application testing, a type of black box testing, we evaluated the functionality of the application from the developer's perspective.
2. **User's perspective.** We included a diverse range of users, including lecturers, students, and the general public. The validation process was conducted using the user acceptance test (UAT) and was facilitated by a comprehensive questionnaire.

The data analysis involved assessing the validity of each statement item using Aiken's V statistical formula, as follows:

$$V = \frac{\Sigma s}{n(c-1)}$$

In this equation, V represents the calculated Aiken's V value, $\sum$s denotes the sum of the frequencies of agreement for each statement item, n signifies the total number of respondents, and c represents the number of categories. The results of Aiken's calculation range from 0 to 1, where a value of 0.6 is particularly significant as it indicates a relatively substantial coefficient. Notably, a V value exceeding 0.6 is considered "valid" according to established standards. The main goal of this study was to gather insights and perspectives from stakeholders, which would provide valuable contributions to the ongoing improvement and refinement of application development efforts in the near future. For more information, please refer to Figure 5, which illustrates the sequence of the research procedures conducted and the current research status in developing the virtual tour application.

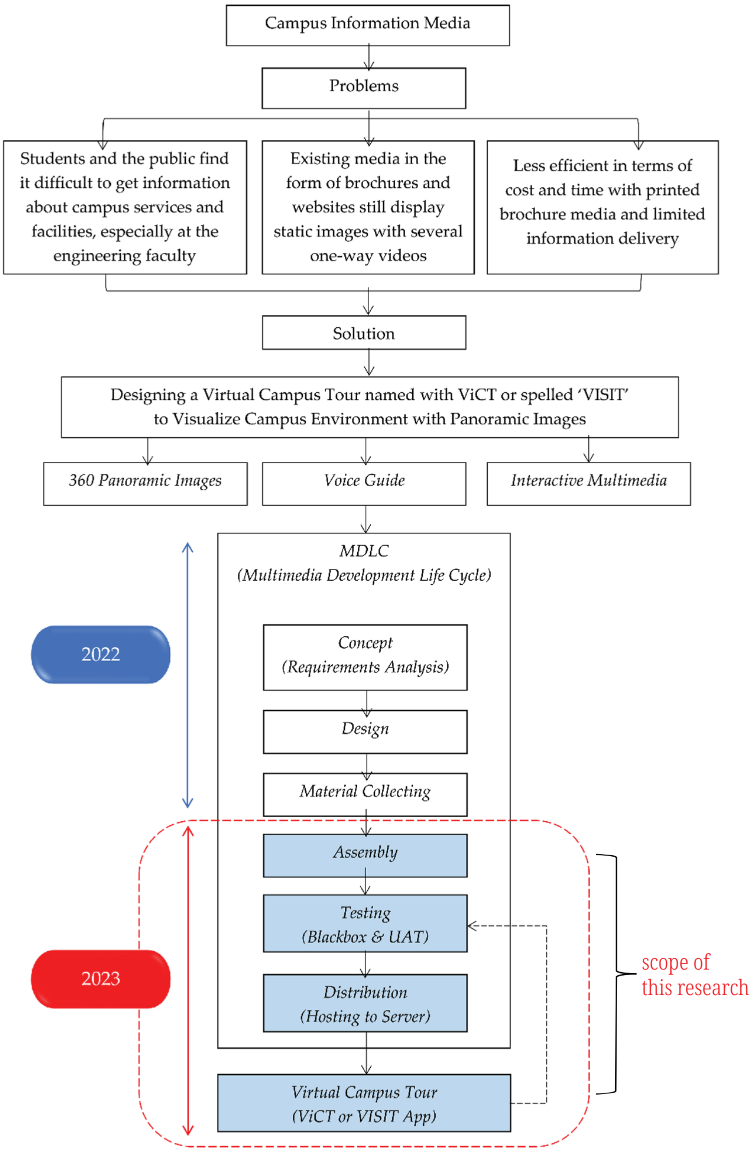

Fig. 5. The research procedure

3.1 Assembly

This phase integrates the previously planned and developed components into cohesive and functional units. The assembly process included implementing various features, functionalities, and content that were planned during the design phase (see Figure 6).

Fig. 6. Overview of the final development process

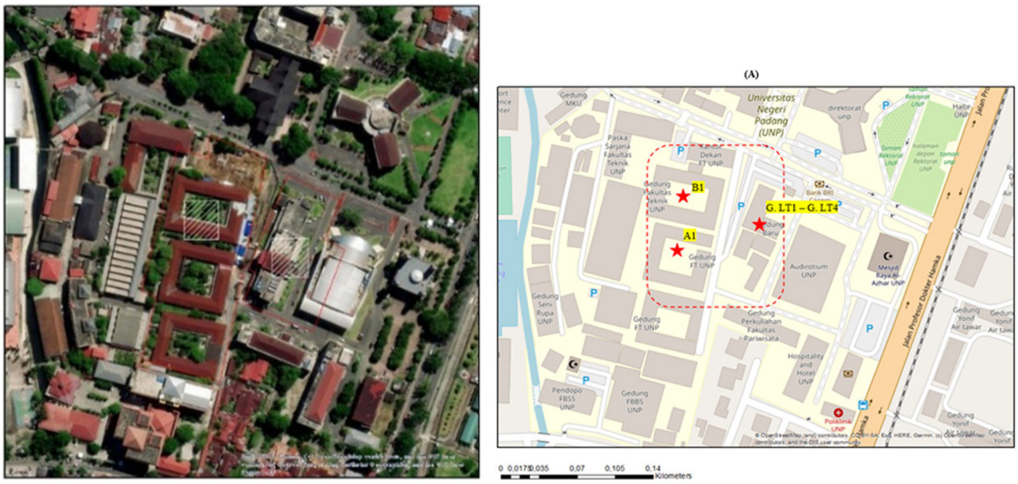

Fig. 7. Study area mapping (A – B) **marked with a red star*

Figure 7 displays the path and location points of the virtual tour. These points (A–B) form the basis for determining the use of storyboards and webpage interfaces. Application development focuses on creating a robust environment for engineering faculty with 20 location points. These points serve as targets for capturing panoramic images. For more detailed information about each location, please consult Table 1. The location points, known as "hotspots," were distributed throughout the three main buildings. These buildings comprised the primary electronic block (A1; B2) and an integrated laboratory building spanning four floors (G. LT1, G. LT2, G. LT3, and G. LT4). The process began with capturing photos of each designated location point and taking 360-degree panoramic images for the virtual tour.

Table 1. Location point list

No.	Building Name	Location Point
1.	Electronics Department Office	A1
2.	VR Laboratory	A1
3.	Animation Laboratory	A1
4.	Electronics Laboratory	A1
5.	Signal Processing Laboratory	A1
6.	Lecturer Room	B1
7.	Computer Laboratory	A1
8.	Communication Systems Laboratory	A1
9.	Library	B1
10.	IoT Laboratory	A1
11.	Classroom E64	A1
12.	Classroom E65	A1
13.	Classroom E66	A1
14.	Lobby	G. LT1, G. LT2
15.	Digital System Laboratory	G. LT2
16.	Computer Network Laboratory	G. LT3

(Continued)

Table 1. Location point list *(Continued)*

No.	Building Name	Location Point
17.	Multimedia Laboratory	G. LT3
18.	Electrical Physics Laboratory	G. LT3
19.	Telecommunication Laboratory	G. LT3
20.	Software Engineering Laboratory	G. LT4

These images visually depict different areas within the tour. After obtaining the pictures, we assembled and organized them into a virtual tour using 3DVista software. During the assembly phase, we collected and connected the panoramic images to ensure a smooth user-browsing experience. The software enabled us to integrate various materials, such as images, design elements, and multimedia components, thereby improving the overall presentation and interactivity of the virtual tours.

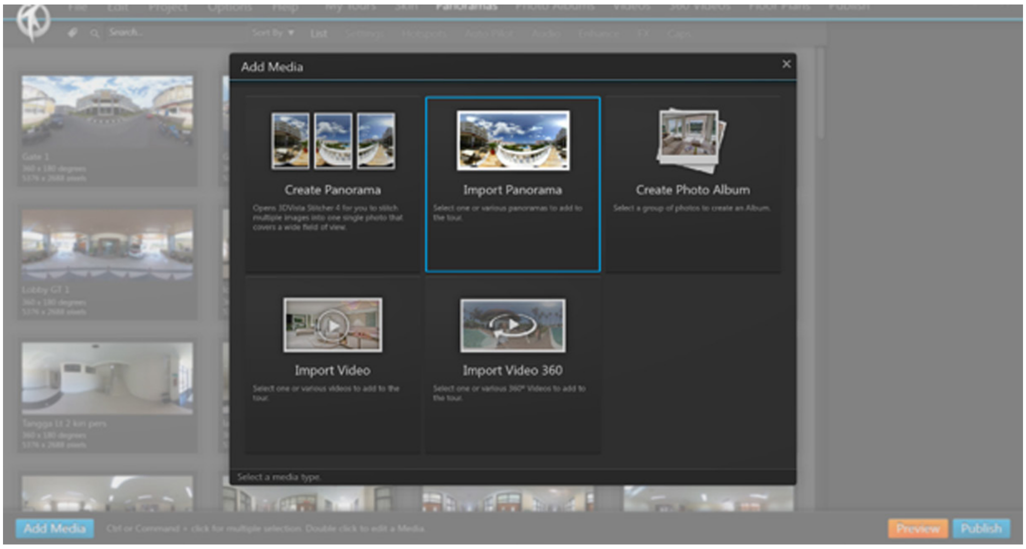

Fig. 8. Import the captured images

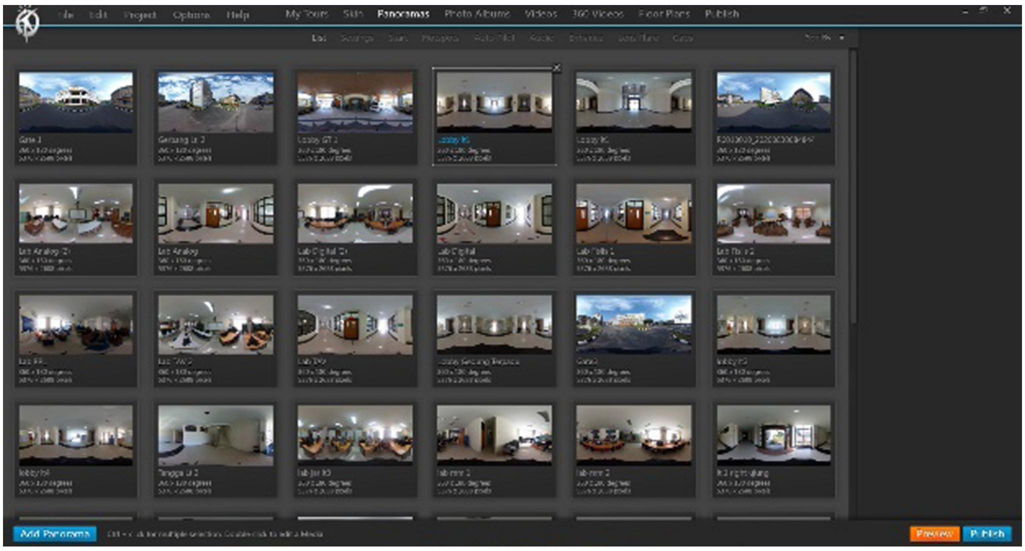

Fig. 9. Assembly process

Figures 8 and 9 demonstrate the process of importing the captured images into the 3D Vista Suite application. This step involves transferring the collected photos to the panorama menu within the application. This import process enables users to choose and upload images taken during the photo capture phase. These images are then organized and stored in the Panorama menu, where they can be accessed and used for further editing and additions to the virtual tour. Users can confidently manage and work with the collected photographs by importing them into the 3D Vista Suite application. This is an essential foundation for the subsequent steps in developing a comprehensive and immersive virtual tour experience. Figure 10 on the following page illustrates the process of calibrating the panoramic display parameters, including the magnification and rotation speeds. These settings enable users to adjust the speed at which a visual representation is magnified or rotated during virtual exploration. The magnification speed parameter allows users to control the speed of expansion or contraction when using the zoom mechanism. By adjusting this setting, users can customize the magnification experience to suit their preferences, making visual interactions smoother and more enjoyable.

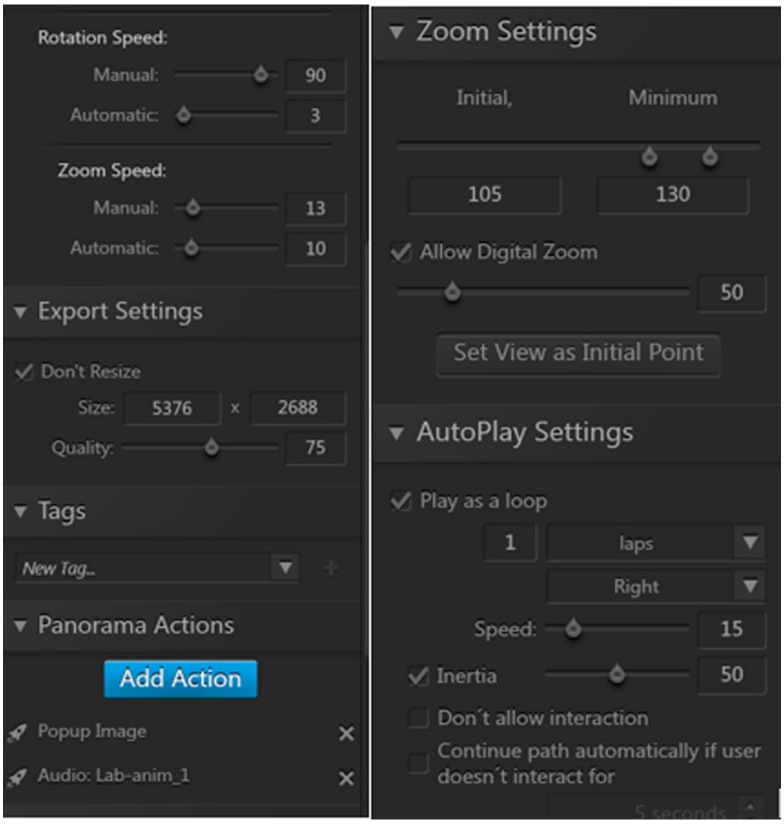

Fig. 10. Panorama display settings

Similarly, the rotation rate parameter enables users to specify the speed at which a visual representation rotates without requiring direct user intervention. This configuration ensures visually appealing and seamless virtual exploration by controlling the movement of the visual representation, regardless of user input. By calibrating the panoramic display parameters, users can enhance the visual elements of virtual exploration, thereby improving their overall visual experience for their target audience. These configurations offer a high level of customization, enabling users to participate in virtual excursions tailored to their specific needs.

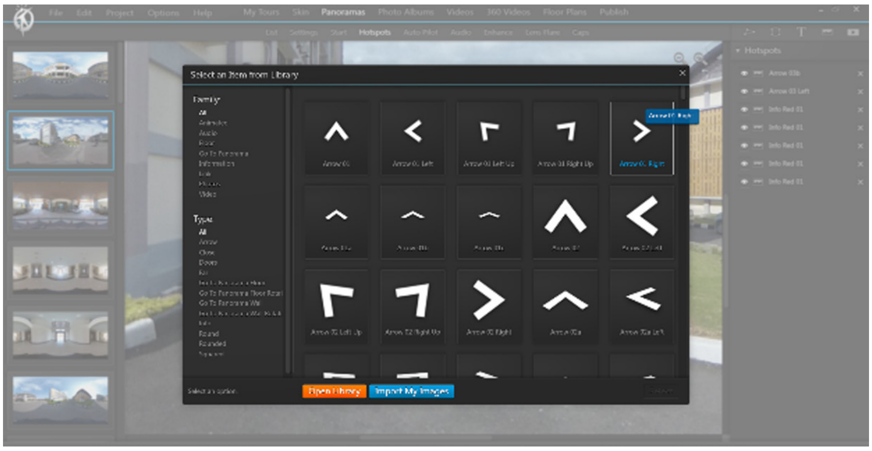

Fig. 11. Hotspot settings

Subsequently, as illustrated in Figure 11, hotspot calibration involves determining the placement of hotspots that serve as connecting elements between the panoramic images. Hotspot calibration also involves supporting actions, such as providing information in text, video, images, audio, and hyperlinks.

Hotspots are interactive elements within virtual exploration that enable users to navigate between locations or points of interest. By strategically placing hotspots within panoramic images, users can enjoy a seamless transition between different areas, creating a unified and immersive experience.

Hotspots can be enriched with various multimedia components, leading to greater engagement and information retention. For example, it is possible to include textual descriptions or clarifications of a specific location. Embedding videos enables the display of dynamic, location-specific content. Images can be included to provide visual references and emphasize important points. Integrating audio allows for the inclusion of audio guidance and ambient sound effects. Links can also be combined to direct users to external websites or other valuable resources.

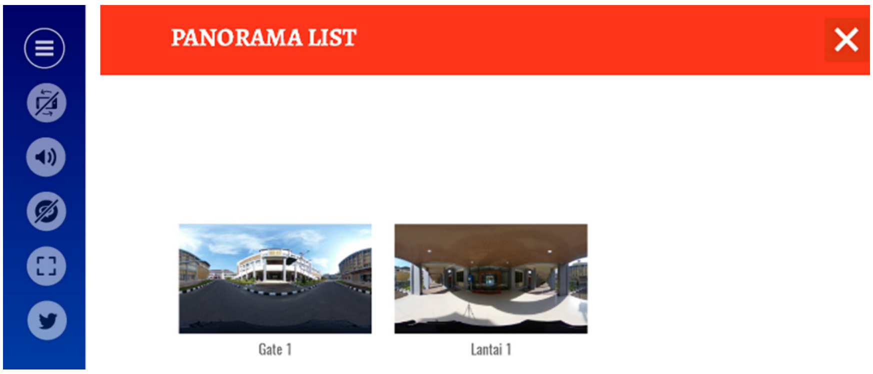

Fig. 12. Overview of the settings buttons

Figure 12 illustrates the settings menu, which includes the rotation control, audio settings, full-screen display options, and social media connectivity. These buttons offer additional and alternative features that enable users to customize their viewing experiences. The rotation control features enable users to adjust the angle or orientation of the virtual exploration, while the audio button facilitates the selection of audio narration or background music. The full-screen view button maximizes the virtual exploration to span the entire screen, offering a more immersive experience.

Finally, connectivity to social media enables users to share their virtual exploration of specific locations on their social media platforms.

In addition, the location list window includes BE and GI structures, which offer a comprehensive index of accessible places within virtual exploration. This enables users to navigate and quickly locate specific destinations or points of interest. Users can instantly access a specific region for examination within the virtual investigation by selecting a location in the index.

The virtual exploration application was encapsulated by integrating all the required materials after completing the assembly process. By offering convenient controls and easy access to various elements and functionalities, we improved the application's user-friendly experience.

3.2 Testing and validation

After completing the assembly phase, we proceeded to the testing phase. During this stage, we executed the virtual tour application and analyzed any potential discrepancies or functional errors. Functional testing was conducted to ensure that the developed virtual tour met the expectations established by the planned and designed operational capabilities.

1. **Black box testing:** This methodology involves conducting tests without a deep understanding of the internal workings of the system or its application. Black box testing primarily focuses on the inputs and outputs generated by the system while neglecting internal processes. This testing approach focuses primarily on evaluating functionality and validating predetermined requirements. Black box testing helps identify defects or functional discrepancies in an application, regardless of its internal implementation.
2. **UAT:** End users or stakeholders conduct this type of testing to verify that the application or system meets predetermined requirements and business needs. UAT aims to examine the application from the user's perspective and certify its actual functionality in an environment similar to everyday usage scenarios. This testing process involves users completing specific tasks within the application and providing feedback on their experiences and satisfaction with the application.

Table 2. Testing criteria

No.	Criteria
1.	The virtual tour page is accessible, clear, and easy-to-understand sentences.
2.	All navigation within the virtual tour functions properly, ensuring a seamless and user-friendly experience for users.
3.	Able to switch locations through the location list.
4.	Able to switch locations using hotspots.
5.	The voice guide from the virtual tour is clear.
6.	Information windows are correctly displayed.
7.	Usage instructions appear on the homepage.
8.	All menus and setting buttons function correctly.

(Continued)

Table 2. Testing criteria *(Continued)*

No.	Criteria
9.	When dragged, panoramic images move smoothly, providing users with a seamless and immersive experience.
10.	The location map accurately shows the coordinates.
11.	The main display (initial point and autopilot) is correct.
12.	This intro (opening part) attracts students' interest in navigating.

Black box testing and UAT are two complementary methodologies aimed at ensuring the quality and functionality of an application. Black box testing focuses on technical aspects and requirements validation, while UAT involves end users to verify that the application meets business expectations and requirements. Both types of testing are crucial in the application life cycle to ensure that the developed application functions effectively and meets the needs of the users and stakeholders involved. The test criteria are shown in Table 2.

3.3 Distribution

The distribution phase is crucial for ensuring that the developed application is easily accessible to the intended users or target demographics. This phase focuses on distributing and delivering the application to designated platforms or channels to ensure its availability for installation or use. This involves packaging the application, preparing installation files or distribution packages, and distributing them through suitable channels.

Creating a dedicated website or landing page specifically for the application is a highly efficient method for distributing a virtual tour application. This approach enables users to access and download an app directly from their web browsers, expanding its accessibility to desktops, laptops, and mobile devices. By offering a centralized online platform, potential users can easily find, access, and download an app, thus improving accessibility. A website or landing page dedicated to a virtual tour app serves as a central source of information about the app's features, functionality, and benefits. It can include download links, installation guidelines, user manuals, interactive demonstrations, and sample virtual tours. This approach facilitates targeted marketing initiatives, search engine optimization, and the attraction of a broader audience through online promotions and advertising. Furthermore, a dedicated website or landing page can be optimized for various devices and platforms, ensuring a seamless experience across different devices. A website or landing page can adjust to different screen dimensions and orientations by incorporating responsive design principles, providing a user-friendly browsing experience.

4 RESULT AND DISCUSSION

4.1 Virtual campus tour application

Users can access the final version of the VICT application via a specific URL or website. This web-based platform offers interactive and immersive virtual tour experiences. Upon accessing the site, users are greeted by a visually appealing and user-friendly interface. The homepage of the application served as the starting point for exploring the virtual tour (see Figure 13). It presented a panoramic view of the starting point, enabling users to preview how they would experience their virtual journey. The interface includes a variety of interactive elements, such as navigation buttons, information windows, and menu options.

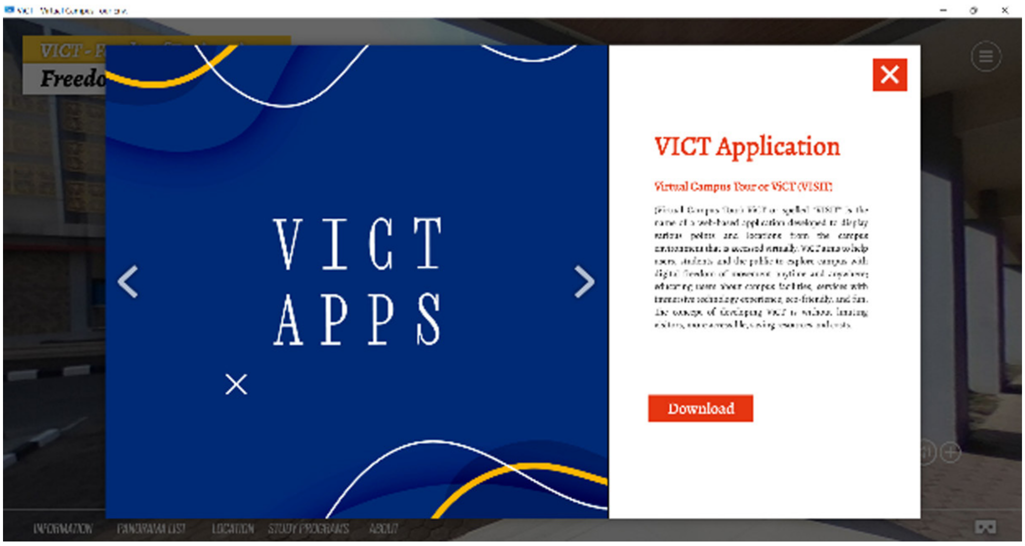

Fig. 13. Final version of the VICT app

Users can navigate smoothly from one place to another on a virtual tour using navigation buttons. Users have the option to choose a specific location from a provided list or utilize hotspot markers embedded in the panoramic images to navigate to new areas. The transition was smooth and enhanced a realistic and immersive experience. Users can access more information about specific points of interest during the virtual tour by interacting with information windows. These windows display text descriptions, images, videos, audio, and links relevant to the location, promoting better comprehension and interaction.

The application also provides customization and social media integration options. Users can customize the settings based on their preferences, including the rotation speed and audio volume. Additionally, they could easily share their virtual tour experiences on various social media platforms, enabling them to spread the word about their favorite places or invite others to participate in virtual exploration. The VICT web application offers a comprehensive and engaging virtual visiting experience. Its intuitive interface, interactive features, and seamless web accessibility make it an ideal platform for users to explore and interact with virtual environments.

4.2 Black box and UAT

We validated the functionality of the virtual tour application to ensure that it aligns with operational objectives and capabilities. We conducted thorough validation, including user input and testing in a simulated environment. Table 3 presents the results, indicating that the validity value is considered “valid” when the coefficient value $V > 0.6$. This validation process leads to continuous improvement, enhancing the usability and performance of the application.

Table 3. Validation results

No.	Criteria	*V* Score	Note
1.	The virtual tour page is accessible, clear, and easy-to-understand sentences.	0.93	Valid
2.	All navigation within the virtual tour functions properly, ensuring a seamless and user-friendly experience for users.	0.84	Valid
3.	Able to switch locations through the location list.	0.96	Valid
4.	Able to switch locations using hotspots.	0.88	Valid
5.	The voice guide from the virtual tour is clear.	0.87	Valid
6.	Information windows are correctly displayed.	0.78	Valid
7.	Usage instructions appear on the homepage.	0.91	Valid
8.	All menus and setting buttons function correctly.	0.89	Valid
9.	When dragged, panoramic images move smoothly, providing users with a seamless and immersive experience.	0.82	Valid
10.	The location map accurately shows the coordinates.	0.87	Valid
11.	The main display (initial point and autopilot) is correct.	0.89	Valid
12.	This intro (opening part) attracts students' interest in navigating	0.87	Valid
Average		**0.88**	**Valid**

The survey was conducted with 105 randomly selected participants. These individuals were then given access to a web-based virtual tour application and asked to provide feedback on the application. The table below displays the students' responses. Based on the findings of the validation process, the average validity score was 0.88. The results obtained fell into the valid category.

The results of the performance tests for the virtual tour application across various browsers and devices are presented in Table 4 and Figure 14. The study evaluated the time it took for the program to load and function on various combinations of browsers and devices. The investigation into page-loading speeds across various browsers and devices revealed surprising results. Among the web browsers assessed on personal computers or laptops, Firefox demonstrated superior performance, with a load time of 2.6 seconds. In terms of performance, Chrome loaded in 2.8 seconds, while Microsoft Edge took slightly longer at 3.0 seconds. The study findings suggest that Firefox and Chrome demonstrate better optimization for loading web pages on personal computers (PCs) and laptops.

Table 4. Loading page testing results

No.	Browser	Device	Time (s)
1.	Firefox	PC/Laptop	2.6
2.	Chrome	PC/Laptop	2.8
3.	M. Edge	PC/Laptop	3.0
4.	Chrome	Smartphone	2.3
5.	Safari	Smartphone	1.7

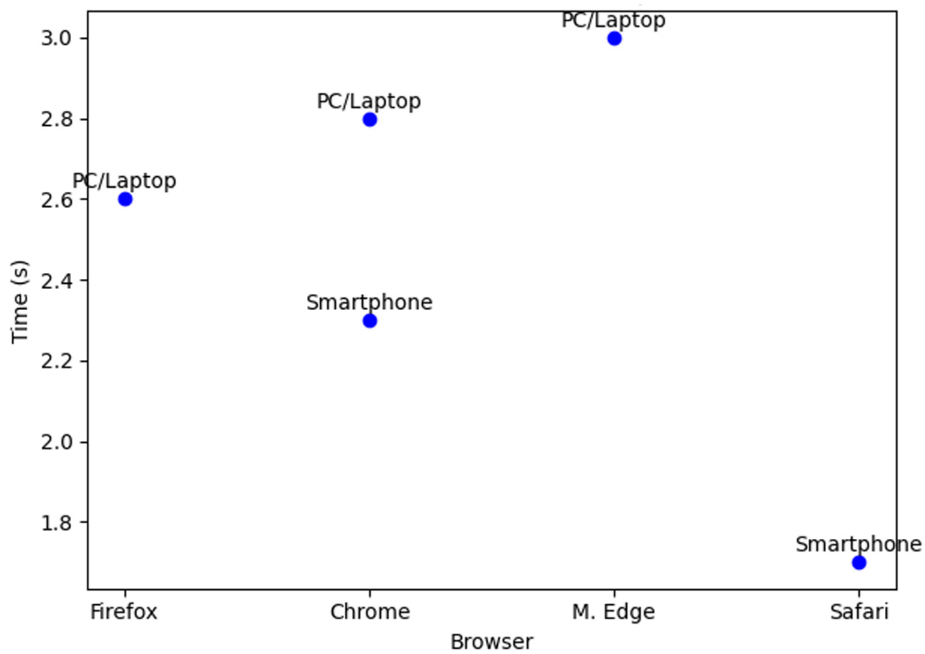

Fig. 14. Browser and device time comparison

A comparison of the loading times for PCs, laptops, and smartphones revealed that smartphones generally have faster loading times. Specifically, Chrome on smartphones achieved a swift 2.3-second load time, while Safari on smartphones led with an even quicker 1.7 seconds. Discrepancies in device processing power and network capabilities are likely responsible for these variations in loading times. These findings provide valuable insights into how various browsers and devices manage load times, highlighting potential opportunities for optimizing page speed and responsiveness. We could conduct additional analysis and testing to gain a better understanding of these variations in load times and to explore ways to improve the quality of the site.

Overall, the evaluation results indicated that the virtual tour application met all the criteria, and users provided positive feedback on their experience with the application. This feedback can help further refine and enhance virtual tour applications in future development. The results of the performance tests provided valuable data on the responsiveness and speed of virtual tour applications across different browsers and devices. This information helps users have an efficient and seamless experience when accessing an application, regardless of their chosen platform.

4.3 The final version of the application

The deployment phase represents the concluding stage after testing. During this phase, the virtual tour developed is stored on a server using a designated domain and made accessible to the general public over an Internet connection. During the deployment phase, a virtual tour application is transferred or installed on a server, allowing remote access through the assigned domain. This approach enables consumers to take a virtual tour by using the URL provided in their web browser. Hosting a virtual tour on a server ensures its availability and allows customers to access it from any location, provided they have an active Internet connection.

A dedicated domain for the virtual tour provides a distinct web address, making it easier for users to locate and access the application (see Figure 15). The objectives of the deployment phase are to ensure that the virtual tour is accessible to potential students, faculty members, and the general public. It is crucial to ensure that the server hosting the virtual tour has the resources and capacity to handle user traffic, ensuring a smooth browsing experience.

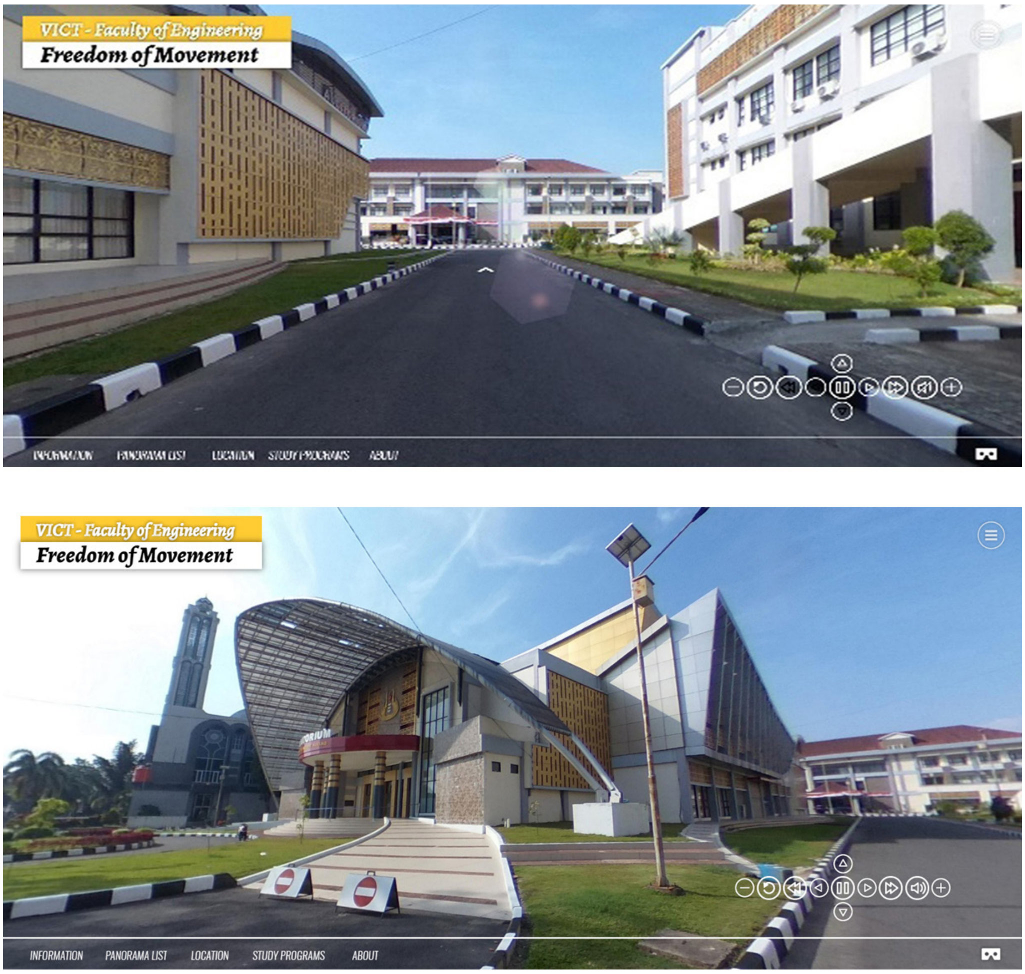

Fig. 15. VICT application

This responsibility involves selecting a reliable hosting service and allocating adequate server resources. Moreover, the distribution phase can facilitate the promotion of virtual tours through various channels, such as social media, micro-content, university websites, and online advertising [35], [36]. These promotional efforts promote awareness and increase user engagement, ultimately expanding the reach and usage of virtual tour applications. In essence, the deployment phase represents the final step, where the approved virtual tour application is hosted on a server with its own unique domain, making it accessible to a global audience via the Internet. The successful implementation of this phase ensures that the virtual tour is widely available, accompanied by promotional strategies to maximize its impact and reach.

5 CONCLUSIONS

In summary, this research investigated the creation of a virtual tour application that encompasses various stages and procedures, starting from the initial concept, progressing through the design phase, and culminating in the assembly, testing, and deployment of the application. The MDLC approach provides a systematic framework for effectively navigating the development process. During the assembly phase, the seamless integration of numerous components results in a functional and cohesive entity that includes the desired features, functionality, and content. This application has undergone rigorous testing, confirming its alignment with the intended objectives and its efficient operation.

The distribution phase involves making an application available to its intended audience. This process involves packaging, preparing installation files, and distributing packages through appropriate channels. The creation of a dedicated website or landing page for a virtual tour application enables user-friendly access and downloads through web browsers. Testing, including black box testing and UAT, is crucial for thoroughly evaluating functionality and usability. The UAT actively involves users in real-world testing scenarios and provides valuable feedback on their overall experience.

The results of black box testing and UAT for virtual tour applications are highly encouraging. The application demonstrated comprehensive functionality and successfully achieved its intended objectives. Furthermore, deploying a program on a server improves user accessibility and enhances the overall online experience. This process involves careful evaluation and selection of a hosting provider, acquiring a domain, configuring the server, uploading applications, and conducting thorough pre-release testing.

The successful development and deployment of virtual tour applications underscores the importance of thorough consideration at various stages, including meticulous planning, design, implementation, testing, and hosting. These steps are crucial for ensuring the delivery of high-quality products and user-friendly experiences. Continuous user feedback remains a crucial component that accelerates application improvement and informs future development.

Moreover, this study addresses the research questions raised in the beginning of this paper.

RQ1: As a web-based application, VICT significantly improves the exploration of outdoor and indoor areas, making it an invaluable tool for prospective students and visitors. Providing an audio guide with essential information, services, facilities, and location-specific details creates an immersive and informative experience, facilitating seamless navigation and enhancing understanding of the campus environment. This enhancement is especially beneficial for individuals who want to familiarize themselves with the campus and make well-informed decisions.

RQ2: The use of 360-degree panoramic image technology has made a significant contribution to the development of VICT. It has been proven to be cost-effective in image production while delivering a highly realistic and immersive visual experience. The integration of this technology has had a positive impact on the application's ability to capture the essence of the campus, enhancing its appeal to users. Furthermore, the outcomes of black box testing and UAT are crucial in ensuring that the application is functional and user-friendly. The user perspective, as revealed through testing, has informed the enhancement of accessibility within campus environments and has paved the way for advancements in the field of virtual tour applications.

This study emphasizes the importance of technological innovation in creating immersive and informative experiences, particularly for individuals navigating unfamiliar environments. The successful development and deployment of VICT underscores the significance of user feedback and continuous refinement to meet the evolving needs of students and visitors. As technology advances, the potential to improve virtual tour applications across various domains remains promising, providing users with new levels of access, engagement, and exploration.

6 LIMITATIONS AND FUTURE WORK

The investigation uncovered numerous limitations and suggested potential directions for future research. It is important to highlight that the virtual tour was limited to the Faculty of Engineering at Universitas Negeri Padang. However, this may compromise the generalizability of the results. Furthermore, it is important to recognize the inherent subjectivity associated with the feedback received through UAT, as individual preferences have the potential to influence it. The emergence of technological constraints, including those imposed by devices and browsers, introduces a new factor that could impact the application's overall performance. The temporal aspect of the study is also noteworthy, as it imposes limitations on the extent of both the exploratory and testing phases. One notable issue that remains unsolved is the explicit consideration of application accessibility for individuals with impairments or special needs, a problem that is still under investigation.

Given the acknowledged limitations, there are promising opportunities for additional research with the potential to expand the scope and impact of virtual tour applications. Exploring the user experience domain further presents a suitable methodology, as it can yield a profound understanding of the intricacies of individuals' perceptions, emotions, and actions, thereby illuminating aspects that require improvement. One of the main priorities is to optimize performance while also conducting a thorough evaluation of usability for diverse user groups. An intriguing expansion involves broadening the scope of testing to encompass a variety of devices and platforms, including applications, within a strong technological framework. Furthermore, it is essential to recognize the importance of complying with accessibility standards to accommodate individuals with disabilities or other specific needs. This aspect has emerged as a critical factor that can potentially improve inclusivity.

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