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Development of a Mobile-Based Ecotourism Guide Application for Tandung Billa Using Geofence and Augmented Reality Technology

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Abstrak

Penelitian ini bertujuan untuk mengembangkan aplikasi panduan ekowisata Tandung Billa berbasis mobile, memanfaatkan teknologi Geofence dan Augmented Reality (AR). Aplikasi dirancang untuk secara otomatis memberikan informasi kontekstual ketika wisatawan berada di lokasi tertentu menggunakan fitur Geofence. Selain itu, teknologi AR digunakan untuk menampilkan objek virtual dan informasi mengenai spot ekowisata seperti Loket Nursery, Apiculture, Aula, Bamba Butterfly, dan Camping Ground. Proses pengembangannya mengikuti metode MDLC (Multimedia Life Cycle). Teknik pengujian sistem menggunakan teknik Black box. Pengujian juga dilakukan oleh ahli dengan memberikan penilaian berupa validasi aplikasi, Untuk menguji kesesuaian aplikasi dengan kebutuhan maka dilakukan uji responden yang diberikan kepada pengguna. Berdasarkan hasil pengujian black box mendapatkan hasil sukses yang berarti semua interface aplikasi telah berfungsi dengan baik, sedangkan untuk penilaian ahli mendapatkan nilai rata rata 98% dari 3 orang validator ahli dibidangnya yang menandakan bahwa aplikasi sangat layak untuk digunakan, sedangkan untuk penilaian responden yang berjumlah 10 responden mendapatkan penilaian 95 dengan kategori sangat layak yang berarti aplikasi ini layak diterapkan di lapangan..

Kata kunci: Augmented Reality, Ekowisata, Mobile Application, Geofence

Abstract

This study aims to develop a mobile-based ecotourism guide application for Tandung Billa, utilizing Geofence and Augmented Reality (AR) technologies. The application is designed to automatically provide contextual information when tourists are at specific locations using the Geofence feature. Additionally, AR technology is employed to display virtual objects and information about ecotourism spots such as the Nursery Ticket Booth, Apiculture Area, Hall, Bamba Butterfly Park, and Camping Ground. The development process follows the Multimedia Development Life Cycle (MDLC) method. System testing was conducted using the Black Box technique. Expert evaluations were also carried out through application validation. To assess the application's suitability for user needs, a user response test was conducted. The results of the black box testing indicated successful outcomes, meaning all application interfaces functioned properly. Expert evaluations, involving three specialists in the field, yielded an average score of 98%, indicating that the application is highly feasible for use. Furthermore, the user evaluation involving 10 respondents resulted in a score of 95, categorized as highly feasible, confirming that the application is suitable for field implementation.

Keywords: *Augmented Reality, Ecotourism, Mobile Application, Geofence*

1. INTRODUCTION

Ecotourism has become one of the rapidly growing sectors in the tourism industry in Indonesia [1], [2], [3], [4]. As a country rich in biodiversity, Indonesia boasts many natural tourist destinations with great potential to attract both domestic and international visitors [5]. One such destination is Tandung Billa, known for its rich natural resources and scenic beauty. However, the main challenge faced by the management of this area is the lack of interactive, real-time information available for tourists. Visits often become limited to visual experiences [6] without comprehensive guides related to the flora, fauna [7], or history of the area [8], [9]. This condition calls for innovations in information presentation to enhance the tourism experience [10].

Previous studies have shown that the use of technology in the tourism sector can improve tourist satisfaction [11]. Augmented Reality (AR) technology has been widely applied in various research

fields, such as education [12], health [13], and tourism [14], capable of presenting information with complete and attractive visualizations via mobile devices. Shows that Geofence technology is proven to be effective in providing automatic location-based notifications or information. The same thing was also concluded by research [15], the use of Geofence makes it easier for users to access relevant information details based on their geographic position. However, research combining these two technologies in the context of ecotourism is still under-explored. moreover, ecotourism has a complex visual variety of objects [16]. This makes the development of AR increasingly complicated [17].

Research by [18] has tried to explore the use of AR integrated with Geofencing in building room-based navigation applications and showed effective and practical results. While [19] tested visitor responses to the use of theme park apps built from AR and Geofencing integration (google maps). The results showed that most respondents gave positive responses. The novelty of this research lies in the development of an ecotourism guide application that simultaneously combines Geofence and AR technology. This approach offers an advantage because it allows tourists not only to receive location-based information but also to engage in an interactive experience through AR visualizations at specific locations. The use of these two technologies is expected to enrich the information received by tourists and enhance the appeal of the Tandung Billa ecotourism area.

Based on this background, the research questions for this study are: (1) How to design an effective mobile-based ecotourism guide application using Geofence and AR technology? (2) How can this application enhance the tourist experience in exploring the Tandung Billa ecotourism area? This study does not have a hypothesis as it adopts a design and system implementation approach.

The main objective of this research is to design and develop a mobile-based ecotourism guide application that utilizes Geofence and AR technology, and to test the effectiveness of this application in improving the tourist experience at the Tandung Billa ecotourism site. The results of this study are expected to make a significant contribution to the development of technology-based ecotourism in Indonesia.

2. MATERIAL AND METHODS

This research uses a Research and Development (R&D) methodology, developing the MDLC (Multimedia Development Life Cycle) model as the software development method. MDCL is a popular method used for interactive multimedia development [20], [21]. The stages of the MDLC model consist of several phases: Concept, Design, Material Collection, Assembly, Testing, and Distribution [22]. MDLC was chosen because it offers a systematic and structured framework for developing multimedia applications, ensuring that each element is well integrated and quality assured.

2.1 Research Stages

2.1.1 Problem Identification

In the Problem Identification stage, the researcher begins by identifying the needs of tourists for a mobile-based ecotourism guide application equipped with Geofence and Augmented Reality (AR) technologies. This application is expected to provide automatic information about important locations and display virtual content such as facts about local flora, fauna, or history interactively. The challenges faced by tourists include a lack of physical markers and limited access to information at the Tandung Billa ecotourism site. Meanwhile, ecotourism managers face difficulties in providing adequate guides and maintaining physical information infrastructure in the area. Geofence technology can assist by sending automatic notifications when tourists approach specific areas [23], while AR can add a richer visual dimension to convey information to visitors [24]. To strengthen the findings, the researcher conducts interviews with both tourists and ecotourism managers, as well as field observations, to gain a deeper understanding of the challenges and opportunities. The results of this stage are then documented as a reference for designing an effective application that meets these needs.

2.1.2 Data Collection

In the Data Collection stage, the researcher conducts surveys and interviews with ecotourism managers and tourists to understand their needs for a guide application based on Geofence and Augmented Reality (AR) technology. The survey of tourists aims to identify user profiles, the types of information they expect while traveling, as well as their experiences and challenges faced during their

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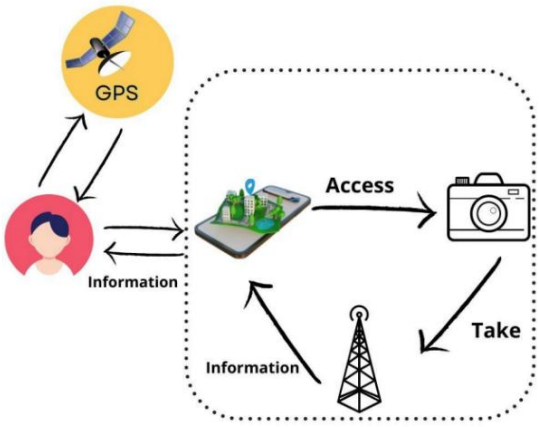
visits. On the other hand, interviews with ecotourism managers focus on operational needs, such as the information that should be provided to tourists and the challenges in providing adequate guide resources. Managers also share insights on the potential use of Geofence and AR technology to help manage the ecotourism area. Additionally, the researcher conducts a location mapping of the Tandung Billa ecotourism site to identify key points, such as flora and fauna habitats, conservation areas, and popular routes often taken by tourists. This data is used to determine where Geofence will be activated and where AR will be applied.

The researcher also collects visual information, such as photos, videos, and 3D models, to be used in the application to enrich the tourist experience. Once the data is gathered, the results of the surveys and interviews are analyzed, and a digital map along with multimedia content are prepared for integration into the application, so that the app can provide interactive information and support conservation efforts.

Picture 1. Digital Map Design

2.1.3 Design



Picture 2. System Architecture Design

Design is the stage of designing an architectural model or prototype that will be developed based on application needs after the concept is defined [25]. The diagram above (Figure 2) illustrates the design of the Tandung Billa ecotourism guide application architecture. The system to be developed is a mobile smartphone application that leverages augmented reality and geofence technology. The augmented reality will be used to display 3D objects in the form of icons representing tourist spots, along with detailed information about the various locations within the Tandung Billa Ecotourism area. This is intended to help tourists discover nearby locations and obtain comprehensive information about the spots they visit.

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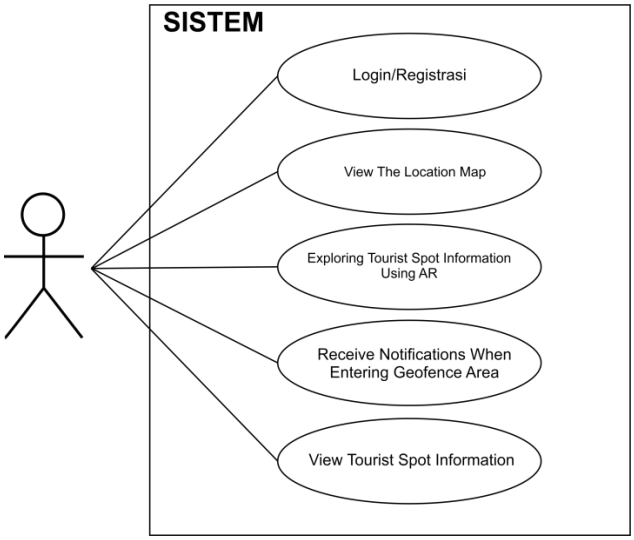

Picture 3. Use case System

Tourist Actor refers to the role of the application user, the tourist, who interacts with the features within the ecotourism guide application. Below is a description of the actions performed by the tourist:

a. Login/Registration: Tourists can create a new account by registering or log into an existing account. This allows users to save preferences, travel data, and gain full access to the application's features.
b. Viewing the Location Map: Tourists can access a digital map displaying their current location, as well as key points in the ecotourism area, such as travel routes, tourist sites, and public facilities. This map helps with navigation and orientation within the tourist location.
c. Exploring Tourist Information Using AR: Tourists can use the Augmented Reality (AR) feature by pointing their phone's camera at a specific location or object. Additional visual information, such as descriptions of the objects, history, or guides, will appear interactively on the screen.
d. Receiving Notifications When Entering a Geofence Area: When tourists approach a predefined area using Geofence technology, the application will send automatic notifications. These notifications may include important information, warnings, or explanations about the area. Viewing Information About Tourist Spots: Tourists can access detailed information about the tourist sites, such as descriptions of the different spots available.

2.1.4 Material Collection

In this stage, all the multimedia materials needed for the application are collected. These materials include:

a. Images and videos to enrich the AR content.
b. Text containing descriptions of the ecotourism spots.
c. Digital maps used to map the ecotourism area and key points where geofencing will be activated.
d. 3D models created for specific objects, such as representations of flora/fauna or geological formations, to be displayed using AR.

2.1.5 Assembly

Assembly is the stage of building and combining various system components from the results of the design stage [26]. This stage is the core of the application development, where all the designed and collected elements are integrated into the system. Development includes coding and integrating Geofence and AR technology into the application.

2.1.6 Testing

Testing is a very important stage in the MDLC method to ensure that the system that has been developed functions properly and meets user needs [27], [28]. Once development is complete, the

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application is tested to ensure all features function as expected. Testing is carried out in several scenarios to verify the performance of the application, particularly the Geofence and AR technologies. Testing includes Geofence testing, AR testing, and interface testing. The system testing technique uses the Black Box method. The testing is also conducted by experts who provide assessments in the form of application validation. The evaluation results for all aspects are measured using a Likert scale[29].

Table 1. Score categories on a Likert scale

score	Criteria
1	Not really worth it
2	Not worthy
3	Decent enough
4	worthy
5	Very worthy

All data using questionnaire techniques are analyzed to obtain percentage results using the following formula [30]:

$$Result = \frac{Total\ score\ obtained}{Maximum\ score} X100\%$$

Eligibility categories are based on the following criteria[31] :

Table 2. Media eligibility criteria

score in percent	Eligibility Category
< 21%	Not really worth it
21-40%	Not worthy
41-60%	Decent enough
61-80%	worthy
81-100%	Very worthy

2.1.7 Distribution

At this stage, the application that has been developed and tested will be distributed to users. This stage includes system installation, delivery to users, and post-implementation monitoring and support.

The implementation involved engaging tourists as the primary respondents through the use of a specially designed questionnaire to measure their responses. The distribution of the questionnaire to tourists aims to evaluate the effectiveness of the application in providing an informative and engaging tourism experience[32]. The questionnaire was designed with a focus on aspects of application effectiveness, such as ease of use, relevance of information, feature reliability, and overall user experience [33], [34]. The results of the analysis were used to evaluate the application's effectiveness and identify areas requiring improvement, such as underperforming features, less intuitive interfaces, or missing information. With this approach, the feedback obtained from tourists helps measure the application's success as an interactive guide and provides insights for further development.

2.2 Tools and Materials

In the research to design and build a mobile-based ecotourism guide application using Geofence and Augmented Reality technology, several important tools and materials are required. These include: A laptop or PC for application development and programming. A smartphone for testing the application on the Android platform. GPS devices to support geofencing functionality. Augmented Reality (AR) software such as Unity for displaying AR content.

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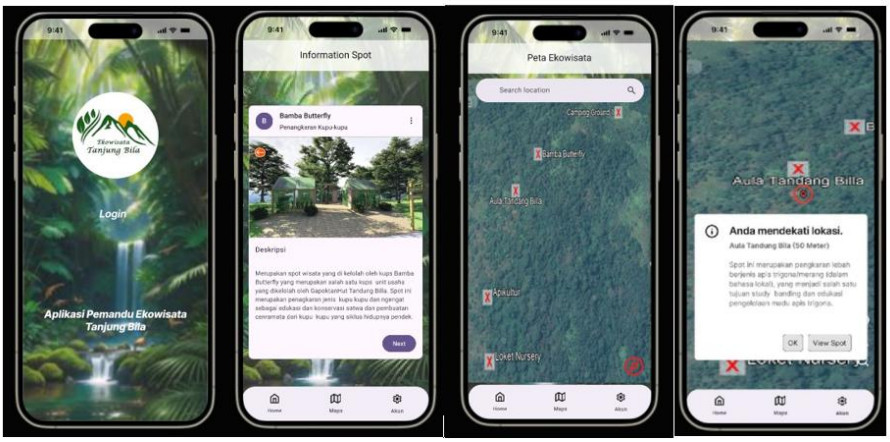
3. RESULTS AND DISCUSSION

3.1. Application Interface



Picture 4. Application Interface Display

1. Initial display of the application

On the main menu there is the application name and displays a login button that can be accessed by the user.

2. Display of ecotourism spot information in AR form

This Ecotourism Information Display in the Form of Augmented Reality is a technology that combines digital elements, such as virtual information or objects, with the real world in real-time. In the context of ecotourism, the display of ecotourism spot information in the form of AR means that users can see information about a tourist spot, flora, fauna, or other interesting objects through the screen of their devices such as smartphones with AR effects.

3. Location map

This feature provides a visual guide for users to find a particular place. In the context of ecotourism, a location map helps visitors know where they are and how to get to an ecotourism spot or other interesting tourist attraction. This map can be a digital map that can be accessed through an application

4. Geofence notification

This technology uses a GPS-based location system to create virtual boundaries around a specific area. When users enter or exit this area, they will receive a corresponding notification. In the context of ecotourism, this feature can be used to provide information or reminders to visitors when they are in a specific location.

3.2. System Testing

The black box is used as the main method to obtain results from the implementation and testing of an application. The application will be tested without examining the internal structure, such as the code or program. Instead, the focus is on the produced application, and functional testing is conducted for each system in the application[35].

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Table 3. Black Box Testing Results of the Tandung Billa Mobile-Based Ecotourism Guide Application Using Geofence and Augmented Reality Technology

Feature Tested	Test Scenario	Expected Result	Notes
Geofence	User enters the geofence area.	Notification appears based on the specified location.	Passed
	User exits the geofence area.	Notifications stop appearing.	Passed
	Test geofence with different radius (100m, 500m, 1km).	Notifications function according to the specified radius.	Passed
	Two geofence areas overlap.	Notifications remain accurate for each area.	Passed
	User uses the app in airplane mode or without an internet connection.	App displays an error message or offline notification.	Passed
	GPS is turned on/off.	App detects the user's location only when GPS is enabled.	Passed
Augmented Reality (AR)	AR elements appear when the camera is directed at specific locations.	AR elements are displayed in the correct position.	Passed
	User moves the device's camera.	AR elements remain stable and follow the object.	Passed
	Compatibility test on devices with different specifications.	AR features run smoothly on all supported devices.	Passed
	App is used under different lighting conditions (day, evening, night).	AR elements remain visible, or the app provides lighting guidance.	Passed
	Device does not support AR.	App displays a polite error message.	Passed
Navigation and UI/UX	User follows the route or path displayed.	Guidance routes are accurate and match the intended destination.	Passed
	User inputs a location outside the geofence coverage.	App displays an error message or "location not found" information.	Passed
	Search feature for tourist attractions by category/keyword.	Search results are accurate and match user input.	Passed
Notifications and Information	Information notifications appear when the user is in specific areas.	Notifications are displayed at relevant times and locations.	Passed
	App displays information about tourist attractions (interesting facts, safety guides).	Displayed information is accurate and relevant.	Passed
Geofence & AR Integration	AR elements only appear if the user is within the geofence area.	AR elements do not appear if the user is outside the geofence area.	Passed
	Location data and AR elements are synchronized with the server.	Location data and AR elements are displayed in real-time without lag.	Passed
Performance	App responds to user location quickly.	Location and AR elements are detected within < 5 seconds.	Passed
	User moves locations quickly (e.g., by vehicle).	App continues to function without interruptions.	Passed
	App is used for > 2 hours.	App remains responsive, and battery consumption is efficient.	Passed
Security	Access to location and camera is managed with user permissions.	App correctly requests permissions before accessing location and camera.	Passed

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	Location data is deleted after the app is closed.	User location data is not stored after the app is closed.	Passed

3.3. Expert Testing

At this stage, testing was conducted by involving three experts to validate the developed application. This testing aimed to determine the feasibility level of the Tandung Billa Ecotourism Guide application in terms of design, content, and other aspects. The testing utilized a questionnaire technique. The questionnaire included questions about the ease of use of the product, perceived benefits, and suggestions for improvement. This questionnaire served as a comprehensive evaluation tool, allowing researchers to collect both qualitative and quantitative data that could be analyzed to assess the application's success. For the quantitative data obtained from the questionnaire responses, the analysis was conducted by presenting the results in percentages using the Likert scale as a measurement tool [36].

Table 4. Validation Results

No	Aspect Description	Assessment Results		
		V I	V II	V III
1.	**Display Aspect**			
	a. The application display looks attractive	5	5	5
	b. The design theme matches the application theme	5	5	5
	c. Placement of writing and button positions	5	4	4
	d. Type of font used	5	5	5
	e. Combination of fonts used	5	5	5
	g. Selection of background colors	5	5	5
	h. Color combinations on the background	5	5	5
	i. Color harmony with other elements	5	5	5
2	**Convenience aspect**			
	a. Ease of understanding the interface	5	5	4
	b. Ease of reading the existing letters	5	5	5
	c. Convenience of viewing the application display	4	5	5
3	**Content/material aspects**			
	a. Conformity of content with the title taken	5	5	5
	b. Completeness of application content	5	5	5
	c. Attractive 3D display	5	5	5
	Total	69	69	68

Dari hasil penilaian yang telah dilaksanakan oleh validator yang tercantum pada tabel 4 di atas dimana nilai total yang didapat VI = 69 , VII= 69, VIII = 68 maka dapat dihitung rata-rata dalam % penilaian ahli aplikasi yang telah dibuat menggunakan rumus :

$$Result = \frac{Total\ score\ obtained}{Maximum\ score} X100\%$$

Table 5. Hasil Analisis nilai Validator

No	Validator	Total Skor	Skor Maksimum	Rata-rata (%)
1	V1	69	70	98,5%
2	V2	69	70	98,5%
3	V3	68	70	97,1%
Rata-rata Skor		68,6	70	98,0% **(Sangat Layak)**

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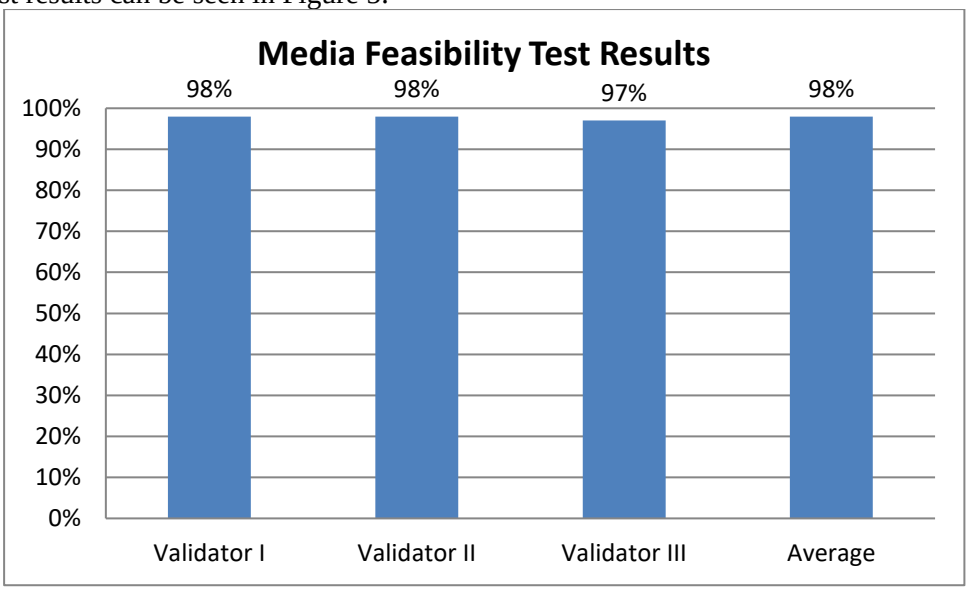
Based on the assessment calculations, the average application validation value was 98%, which met the criteria so that the test results were declared Very Appropriate. The graph of the application feasibility test results can be seen in Figure 5.



Picture 5. Expert Testing Results Graph

3.4. Device Testing

Pengujian pada berbagai sistem operasi dan tipe perangkat sangat penting dalam pengembangan aplikasi mobile untuk memastikan bahwa aplikasi dapat berjalan dengan baik di berbagai kondisi dan perangkat yang digunakan oleh pengguna. Kegunaan utama pengujian ini adalah untuk mengetahui kompatibilitas Sistem Operasi kemudian memastikan aplikasi dapat berjalan tanpa masalah pada berbagai versi sistem operasi Android selain itu juga untuk menguji Kompatibilitas dan performa diberbagai tipe perangkat[37]. The test results can be seen in the following table 6.

Table 6. Application Test Results

Test Type	Device A (High-end)	Device B (Mid-range)	Device C (Low-end)
Versi OS	Android 14	Android 13	Android 12
Prosesor	Snapdragon 8 Gen 3	MediaTek Dimensity 1200	MediaTek Helio G70
RAM	8 GB	6 GB	4 GB
Storage	128 GB	64 GB	32 GB
Screen Resolution	1440 x 3200	1080 x 2400	720 x 1600
Connectivity	5G, Wi-Fi 6	4G, Wi-Fi 5	4G, Wi-Fi 4
Application Testing Duration	1 hour	1 hour	1 hour
Geofence Testing	Accurate, responsive with 50-100-500 zones	Accurate, responsive with 50-100-500 zones	Accurate with 50-100 zone
Augmented Reality (AR) Testing	AR is smooth, no lag	AR lags a bit, graphics are medium	AR is slow, graphics are low
Functionality Testing	All features work fine	Semua fitur berjalan dengan baik	Some features are not optimal

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Performance Testing (Responsiveness)	Very responsive	Quite responsive	Feels a little slow
Battery Life Testing	4 hours of active use	3 hours of active use	2 hours of active use
Compatibility Testing	Compatible with many devices	Compatible with multiple devices	Limited to certain devices
Graphics and Visual Testing	Smooth and clear AR graphics	Medium AR graphics, slight lag	Low AR graphics, looks broken
Loading Process Speed	Fast (1-2 seconds)	Medium (3-5 seconds)	Slow (more than 5 seconds)

From the table above, it can be concluded that the Tandung Billa Ecotourism Introduction application is optimal if run on an Android device that supports Android OS specifications 12 and above and RAM above 4 GB, and does not support if using an old Android system that still uses an Android OS system below Android 12 with 4 GB of RAM. Based on the testing above, the author concludes that the recommended device for running the application is with Android OS 14, 8 GB of RAM, for the minimum recommendation, namely 4 GB of RAM with Android OS 12.

3.4. User Respondent

At this stage, the application was directly used by six visitors and four ecotourism managers who would eventually use the application. This process aimed to evaluate the application's effectiveness in terms of system reliability, ease of use, and user experience, as well as to gather feedback from users regarding their experiences while using the application [38]. The results of the testing conducted with user respondents can be seen in Table 7 below:

Table 7. Results of the Respondent's Assessment

Aspek Penilaian	skor	Skor maksimum	Persentase %	Kategori
Geofence based features work according to the specified location	4.8	5	96	Very good/ Very worthy
The augmented reality (AR) feature displays information with high accuracy.	4.7	5	94	Very good/ Very worthy
The application can be used without any significant interruptions or errors.	4.9	5	98	Very good/ Very worthy
The application interface is easy to understand.	4.7	5	94	Very good/ Very worthy
Navigation within the application is easy to understand	4.7	5	94	Very good/ Very worthy
Geofence and AR features are easily accessible without additional instructions.	4.6	5	92	Very good/ Very worthy
The application provides an interesting experience during ecotourism exploration.	4.7	5	94	Very good/ Very worthy
The AR feature provides interactive and easy-to-understand information.	4.6	5	92	Very good/ Very worthy

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How do you respond to the information displayed by the application regarding ecotourism?	4.9	5	98	Very good/ Very worthy
The app helps you find ecotourism locations more easily?	4.9	5	98	Very good/ Very worthy
Did the app improve your understanding of ecotourism objects?	4.7	5	94	Very good/ Very worthy
Does the app help you plan your travel more effectively?	4.8	5	96	Very good/ Very worthy
Average Score	**47,5**	**5**	**95**	**Very good/ Very worthy**

From the table above, it can be seen that from the assessment items from the questions given to respondents, the assessment results are in the category of very suitable for use , so it can be concluded that the Android-based Tandung Billa ecotourism introduction application is suitable for use in Tandung Billa ecotourism.

Overall, the test results indicate that the mobile-based ecotourism guide application, utilizing geofence and augmented reality technology, functions well, is stable, and provides a beneficial and interactive experience for users. Some minor adjustments may be needed to further optimize data usage and AR performance on devices with lower specifications. However, overall, the application is ready for use in the field.

5. RESEARCH DISCUSSION

This research aims to develop an Android-based application for introducing the Tandung Billa Ecotourism site by implementing 3D modeling. This application can be used by users to promote the ecotourism site and can also be used by visitors to explore it. The research method employed is Research and Development (R&D), with the stages including observation, interviews, and literature review. The next steps involve analyzing the needs, followed by system design to be developed. System design is carried out using the Unified Modeling Language (UML) method, including use case diagrams and activity diagrams. The system application is then developed using Unity 3D software to create the application interface, with modeling done using SketchUp. Testing is performed using the black box method to evaluate the functionality of the application interface. Expert testing is also conducted to assess the application's functionality, as well as device testing to determine the application's performance on various devices. Additionally, field testing with respondents is carried out to evaluate the application's usability in real-world scenarios.

The main difference between this Android-based Ecotourism Introduction application for Tandung Billa, with 3D modeling implementation, and other relevant research is in the navigation model, which uses a 3D panorama view. In contrast, other studies use an analog mode. The advantage of this application is that it can be easily developed to modify the 3D view with original panorama images from the Ecotourism site, with a relatively small application file size. However, the drawback of this application is that the panorama images are not fully accurate to the real-world setting, as they only represent a 3D design panorama and animation. Additionally, the application's interface is somewhat static and could still be improved and developed further.

6. CONCLUSION

This research has met expectations, namely developing a mobile-based Tandung Billa ecotourism guide application by integrating Geofence and Augmented Reality (AR) technology.. The application is designed to automatically provide contextual information when users are at specific locations and to display virtual objects at key ecotourism points such as the Nursery Ticket Booth, Apiculture Area, Hall, Bamba Butterfly Park, and Camping Ground. The development process followed the Multimedia Development Life Cycle (MDLC) method to ensure a structured and systematic approach.

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The testing results indicate that the application meets functional and usability standards. Black box testing confirmed that all interfaces operate correctly. Expert validation from three specialists yielded an average score of 98%, while user testing involving 10 respondents resulted in a 95% rating categorized as "highly feasible." These findings demonstrate that the application effectively enhances the ecotourism experience and serves as an educational tool in the context of technology-based conservation tourism.

However, this study has certain limitations, particularly the relatively small number of respondents and the limited testing area, which focused solely on a single ecotourism site. Future research should consider expanding the implementation to other ecotourism destinations and developing additional interactive features, such as interest-based recommendations or artificial intelligence integration. With further refinement, the application has the potential to become a sustainable solution in supporting environmental conservation, education, and the promotion of local ecotourism through technology.

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REFERENCES

[1] A. Firman, M. Moslehpour, R. Qiu, P.-K. Lin, T. Ismail, and F. F. Rahman, “The impact of eco-innovation, ecotourism policy and social media on sustainable tourism development: evidence from the tourism sector of Indonesia,” *Economic Research-Ekonomska Istraživanja*, vol. 36, no. 2, p. 2143847, 2023.

[2] S. Sisriany and K. Furuya, “Understanding the Spatial Distribution of Ecotourism in Indonesia and Its Relevance to the Protected Landscape,” *Land (Basel)*, vol. 13, no. 3, p. 370, 2024.

[3] S. H. Wiyono, A. Subianto, and N. Nuhman, “Sustainable Ecotourism Development and Community Empowerment: A Case Study of the Center for Environmental Education in Seloliman Village, Indonesia,” *Society*, vol. 11, no. 2, pp. 310–328, 2023.

[4] M. Setini, I. Wardana, I. Sukaatmadja, N. Ekawati, N. Yasa, and I. Astawa, “Policy models for improving ecotourism performance to build quality tourism experience and sustainable tourism,” *Management Science Letters*, vol. 11, no. 2, pp. 595–608, 2021.

[5] S. Wijaya, “Indonesian food culture mapping: a starter contribution to promote Indonesian culinary tourism,” *Journal of Ethnic Foods*, vol. 6, no. 1, pp. 1–10, 2019.

[6] Z. Kia, “Ecotourism in Indonesia: Local community involvement and the affecting factors,” *Journal of Governance and Public Policy*, vol. 8, no. 2, pp. 93–105, 2021.

[7] K. Cheruiyot and K. Moenyane, “Exploring the potential of adopting geofence mobile technology in the South African retail sector,” *Cogent Business & Management*, vol. 11, no. 1, p. 2327126, 2024.

[8] S. I. Uliganets, U. Y. Shynkarenko, L. V Melnyk, M. A. Molochko, and S. Y. Syrovets, “Analysis of natural prerequisites for the development of ecotourism in nature conservation areas (on the example of the Pyryatynskyi National Nature Park),” *Journal of Geology, Geography and Geoecology*, vol. 32, no. 4, pp. 859–870, 2023.

[9] H. Mekonnen and S. Mekonen, “Potentials, opportunities and challenges of ecotourism development in selected historical and sacred sites of North Shewa Zone, Amhara region, Ethiopia,” *International Journal of Tourism Cities*, vol. 10, no. 3, pp. 737–756, 2024.

[10] T. Pencarelli, “The digital revolution in the travel and tourism industry,” *Information Technology & Tourism*, vol. 22, no. 3, pp. 455–476, 2020.

[11] D. Prasti, F. N. Yasir, M. A. Taslam, and R. Rosmiati, "Perancangan Aplikasi Android 3D Modelling Ekowisata Tandung Billa," in *Prosiding Seminar Nasional Pemanfaatan Sains dan Teknologi Informasi*, 2023, pp. 59–66.
[12] J. Garzón, "An overview of twenty-five years of augmented reality in education," *Multimodal Technologies and Interaction*, vol. 5, no. 7, p. 37, 2021.
[13] Y. Baashar, G. Alkawsi, W. N. Wan Ahmad, M. A. Alomari, H. Alhussian, and S. K. Tiong, "Towards wearable augmented reality in healthcare: a comparative survey and analysis of head-mounted displays," *Int J Environ Res Public Health*, vol. 20, no. 5, p. 3940, 2023.
[14] M. H. Ronaghi and M. Ronaghi, "A contextualized study of the usage of the augmented reality technology in the tourism industry," *Decision Analytics Journal*, vol. 5, p. 100136, 2022.
[15] S. Veni, R. Anand, and D. Vivek, "Driver assistance through geo-fencing, sign board detection and reporting using android smartphone," in *Soft Computing for Problem Solving: SocProS 2018, Volume 2*, Springer, 2020, pp. 361–372.
[16] Y. Ye, "Big Data Visual Accounting Model for Ecotourism Carrying Capacity," in *International Conference on Innovative Computing*, Springer, 2023, pp. 971–978.
[17] N. Ashtari, A. Bunt, J. McGrenere, M. Nebeling, and P. K. Chilana, "Creating augmented and virtual reality applications: Current practices, challenges, and opportunities," in *Proceedings of the 2020 CHI conference on human factors in computing systems*, 2020, pp. 1–13.
[18] M. Lu *et al.*, "Indoor AR Navigation Framework Based on Geofencing and Image-Tracking with Accumulated Error Correction," *Applied Sciences*, vol. 14, no. 10, p. 4262, 2024.
[19] C. M. Chan and S. L. Lau, "Using augmented reality and location-awareness to enhance visitor experience: A case study of a theme park app," in *2020 IEEE Graphics and Multimedia (GAME)*, IEEE, 2020, pp. 49–54.
[20] A. R. Hakim, A. R. Hasibuan, and P. P. Hariani, "Implementation of Multimedia Development Life Cycle in Learning Media Applications for Children with Mental Disabilities," *Hanif Journal of Information Systems*, vol. 2, no. 1, pp. 11–21, 2024.
[21] D. Aryani, N. Noviandi, N. S. Fatonah, and H. Akbar, "Implementation of the Multimedia Development Life Cycle (MDLC) in Solar System Application Design," *International Journal of Science, Technology & Management*, vol. 5, no. 4, pp. 726–732, 2024.
[22] I. I. D. Yusuf, M. Jahiri, H. Henderi, and A.-B. Bin Ladjamudin, "Design and Development of Interactive Media in Vocational High Schools Using the Multimedia Development Life Cycle Method Based on Android," *JINAV: Journal of Information and Visualization*, vol. 5, no. 1, pp. 134–145, 2024.
[23] R. Ivanov, "Exhibitxplorer: Enabling personalized content delivery in museums using contextual geofencing and artificial intelligence," *ISPRS Int J Geoinf*, vol. 12, no. 10, p. 434, 2023.
[24] R. Hammady, M. Ma, and C. Strathearn, "Ambient information visualisation and visitors' technology acceptance of mixed reality in museums," *Journal on Computing and Cultural Heritage (JOCCH)*, vol. 13, no. 2, pp. 1–22, 2020.
[25] I. Y. Ruhiawati, A. P. Candra, and S. N. Sari, "Design and Build a Multimedia System for Indonesian Religious Activities Based on Android," *International Journal of Cyber and IT Service Management*, vol. 1, no. 2, pp. 233–239, 2021.
[26] Dwi Intan Af'idah, "Virtual Tour As A Tourist Attraction Promotion Media Using Multimedia Development Life Cycle," *International Conference On Digital Advanced Tourism Management And Technology*, vol. 1, no. 1, pp. 253–266, Dec. 2023, doi: 10.56910/ictmt.v1i1.68.
[27] S. D. M. Sumual, H. R. Lumapow, P. E. A. Tuerah, C. J. H. Dondokambey, W. R. L. Paat, and Y. B. Manumpil, "Development of Multimedia-Based Learning Media for Multimedia Courses," *International Journal of Information Technology and Education*, vol. 3, no. 3, pp. 1–10, 2024.
[28] I. Ismail *et al.*, "The usefulness of an Augmented Reality-based Interactive 3D Furniture Catalog as a Tool to Aid Furniture Store Sales Operations," *IJCCS (Indonesian Journal of Computing and Cybernetics Systems)*, vol. 16, no. 4, pp. 345–356.
[29] S. Arikunto, Dasar-dasar evaluasi pendidikan edisi 3. Bumi aksara, 2021.
[30] N. Sari and I. Anugraheni, "Pengembangan media pembelajaran berbasis Android pada pembelajaran tematik kelas IV tema 6 subtema 1 di sekolah dasar," JGK (Jurnal Guru Kita), vol. 5, no. 2, pp. 33–43, 2021.
[31] G. P. P. Hapsari and Z. Zulherman, "Pengembangan media video animasi berbasis aplikasi canva untuk meningkatkan motivasi dan prestasi belajar siswa," J. basicedu, vol. 5, no. 4, pp. 2384–2394, 2021.

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INFORMATIKA SAINS DAN TEKNOLOGI

[32] T. F. Manik, U. Sulistiyo, and B. A. Wulandari, "Pengembangan Modul Tenses Bahasa Inggris Siswa," J. Educ. Instr., vol. 4, no. 2, pp. 1–9, 2021.
[33] G. M. Adi and I. W. Sujana, "Pengembanagan Perangkat Pembelajaran Berbasis Problem SlolvingTri Hita Karana Materi Keragaman Budaya Kelas IV SD," J. Edutech Undiksha, vol. 9, no. 1, pp. 113–121, 2021.
[34] K. S. Kartini and I. N. T. A. Putra, "Respon Siswa Terhadap Pengembangan Media Pembelajaran Interaktif Berbasis Android," J. Pendidik. Kim. Indones., vol. 4, no. 1, p. 12, 2020.
[35] M. T. Abdillah, I. Kurniastuti, F. A. Susanto, and F. Yudianto, "Implementasi black box testing dan usability testing pada website Sekolah MI Miftahul Ulum Warugunung Surabaya," *J. Comput. Sci. Vis. Commun. Des.*, vol. 8, no. 1, pp. 234–242, 2023.
[36] M. Z. Paputungan, M. Ahsanuddin, and M. K. Amrullah, "Pengembangan Aplikasi Mobile untuk Pembelajaran Bahasa Arab dengan Pendekatan Kontekstual," Al-Kilmah J. Pendidik. Bhs. Arab dan Hum., vol. 3, no. 1, pp. 1–15, 2024
[37] M. A. Yahya, T. Wahyuningrum, and N. A. Prasetyo, "Usability Testing pada Prototype Aplikasi Mobile PlayKids Menggunakan USE Questionnaire," J. Appl. Comput. Sci. Technol., vol. 3, no. 1, pp. 169–178, 2022
[38] J. R. P. Pradhana et al., "Pengujian Usability untuk Mengetahui Kepuasan Pengguna pada Website Perpustakaan Institut Teknologi Telkom Purwokerto," J. ICTEE, vol. 2, no. 1, pp. 36–41, 2021