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Revolutionizing Ethnographic Collection Introduction through Augmented Reality Technology in Museum

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Abstract

The North Sulawesi Provincial State Museum is one of the tourist destinations that offers a profound experience in exploring the historical, cultural, and tourism heritage of Indonesia. Visitors can learn about various valuable historical collections, including ethnographic collections, which hold significant historical value. However, the information provided about the ethnographic collection is very limited, making it challenging for visitors to understand and appreciate it. This research aims to develop an application for recognizing the museum's ethnographic collection using Augmented Reality (AR) technology, which will make it easier for visitors to obtain information about the collection. This application was designed and developed using the Multimedia Development Life Cycle (MDLC) method, which consists of six stages: conceptualization, design, material gathering, assembly, testing, and distribution. The result of this research is an Android-based AR Museum application that can display information about the ethnographic collection in the form of text, sound, and 3D images. This application can enhance the visitor experience, especially in understanding and appreciating the cultural heritage and traditions represented in the ethnographic collection of the North Sulawesi Provincial State Museum. Additionally, this application can improve the accessibility of information about the ethnographic collection and promote the museum as a center for heritage preservation, education, and culture.

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INTRODUCTION

According to the International Council of Museums, a museum is a permanent nonprofit institution that serves the community and is open to the public [1]. Its purpose is to acquire, preserve, research, communicate, and exhibit the tangible and intangible heritage of humanity and its environment for educational, study, and enjoyment purposes [2][3]. The North Sulawesi Provincial State Museum is one of the tourist destinations that offers a profound experience in exploring historical, cultural, and tourism heritage [4]. Officially inaugurated on January 9, 1991, the primary goal of establishing this museum is to collect, preserve, and exhibit all materials and documents related to the local culture, history, and art of North Sulawesi Province. The museum boasts a diverse and comprehensive collection that spans ten different categories, including geology, biology, ethnography, archaeology, history, numismatics (currency collection), philology, ceramology, art, and technology. In total, the museum houses 2,810 collections, with approximately 500 collections on public display. The ethnographic collections stored in this museum hold significant historical value and untold stories. However, the

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presentation of information about these ethnographic collections has some limitations, such as the lack of descriptions for certain items and the reliance on text-heavy paper displays.

Based on observations of visitors during their visits to the museum, a common problem faced is their perception of the information presented as uninteresting and monotonous, resulting in visitor boredom. In addition, the lack of interactive media regarding the collection is considered to be the cause of the lack of information content. Museum-goers do not always have access to guides who can provide detailed explanations of the displayed collections, not only in North Sulawesi Provincial State Museum but also in most museums [5]. As of now, the North Sulawesi Provincial State Museum lacks interactive media for introducing its collections. Consequently, many visitors, especially children, struggle to understand the presented information, especially when it is not presented visually. This limitation restricts the dissemination of information about the museum's collections, particularly its ethnographic collection.

To expand and simplify access to information about the collections at the museum and to enhance public interest in visiting the museum, the use of appropriate technology is necessary [6] [7] [8]. This would make the museum's collections more informative and accessible to anyone interested in understanding the ethnographic collections as part of the cultural heritage [8] [9] held by the North Sulawesi Provincial State Museum.

The development of Augmented Reality (AR) technology has made significant contributions across various fields, including advertising, architecture, construction, entertainment, medicine, the military, and tourism [10]. One of the applications of AR technology is in museums. Previous studies have confirmed the relationship of intermediary influence between augmented reality in museums and learning effectiveness [11]. With AR technology, users can visualize museum objects or collections in three dimensions, allowing them to obtain visual information [12]. According to Mursyidah and Ramadhona, in their research, they successfully created an application using marker-based tracking augmented reality technology [13]. This application can display animations of traditional Acehnese houses and 9 3D objects representing traditional Acehnese items. Furthermore, Aishiyah and Andryanto, in their research, developed a tour guide application capable of projecting 3D objects through augmented reality technology onto Android smartphones[6].

Previous research about the use of Augmented Reality (AR) in the Bank Indonesia Museum draws attention to augmented technology, making it more appealing for people to visit the museum. The implementation of AR has led to an increase in visitors to the Museum Bank Indonesia, which in turn boosts the museum's revenue. With higher income, the museum can better maintain its collections and allocate funds to explore or acquire new historical objects or collections for the museum [14]. Another research on the development of augmented reality for cultural education reveals that AR applications enable users to access and explore the museum's virtual collection and learn about the associated culture without needing to physically visit the museum [15].

The utilization of augmented reality technology in museums, as revealed in previous research, can aid in introducing, preserving, and exhibiting historical objects. Many existing AR applications in museums are designed to enhance the on-site visitor experience, adding layers of information to physical exhibits [16]. This technology offers convenience for visitors in obtaining information about historical objects within the museum and how it can be used to teach users about cultural heritage and historical context [17].

In this study, an Android-based Augmented Reality (AR) application is being developed as an informational tool using marker-based tracking. The application will display virtual 3D objects along with text, images, and audio information about the ethnographic collections of the North Sulawesi Provincial State Museum. This AR application will be built on the Android platform using the Vuforia Software Development Kit (SDK) in Unity. The application will significantly expand access to the museum’s ethnographic collections by allowing users to engage with the artefacts through their mobile devices, regardless of their physical location. By integrating text, images, and audio, the application

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provides a comprehensive educational experience, particularly benefiting younger audiences by making learning about local culture and history more interactive and engaging. The AR application contributes to the preservation and promotion of local culture by providing a digital platform through which ethnographic collections can be showcased and understood more deeply. The development aims to enrich the visitor experience by offering an immersive and interactive way to explore museum collections, thereby enhancing interest in the museum and its cultural offerings. Furthermore, the application supports the museum's role as a center for education and cultural heritage preservation, reinforcing its importance in the community and potentially attracting more visitors and educational collaborations.

METHODS

Data Collection Methods

The data collection techniques employed are as follows: (1) **Observation**: Data collection was conducted through direct observation, involving note-taking and careful examination. This observational method was used to closely examine the ethnographic collections present at the North Sulawesi Provincial State Museum. (2) **Interview**: Data collection was carried out through interviews, wherein the author engaged in direct interaction with Mr. Drs. Ferdy Tamarindang, the head of UPTD Taman Budaya and the North Sulawesi Provincial State Museum. Through question-and-answer sessions, the author gathered the required information. (3) **Questionnaire**: Used as a tool for data collection, a series of questions were posed to respondents to obtain their responses to the inquiries. Two types of surveys were employed: open-ended and closed-ended. Closed-ended surveys provided predetermined response options to respondents, focusing on ideal choices. Conversely, open-ended surveys allowed respondents to express their perspectives without predetermined response options. In this research, a questionnaire with a combination of open and closed-ended questions, as well as a suggestion box, was used. The information-gathering strategy using polls was utilized to assess the comfort level of the product from a user perspective.

Software Development Methodology

The methodology used in developing multimedia in this study is the Multimedia Development Life Cycle (MDLC) Sutopo version which includes the Concept, Design, Material Collecting, Assembly, Testing, and Distribution stages [18].

Figure 1. Multimedia Development Life Cycle (MDLC)

Conceptualization

The initial stage of the conceptualization process involves identifying the type of product to be created, which requires collaboration and communication with relevant parties. In this exploration, the

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focus is on creating an Augmented Reality application to introduce ethnographic collections at the North Sulawesi Provincial State Museum. The communication involved interviews with Mr. Drs. Ferdy Tamarindang, the head of UPTD Taman Budaya, and the North Sulawesi Provincial State Museum. These interviews played a crucial role in identifying issues related to collection presentation at the museum and evaluating the issues presented through hypotheses.

The identified problems became more detailed based on interview results by conducting direct observations on-site. To address these issues, researchers and the North Sulawesi Provincial State Museum collaborated to find alternative solutions, namely the creation of an augmented reality museum application to increase visitor interest in getting to know the ethnographic collections in the museum. This collaboration resulted in product specifications (AR Museum Application) being developed. Furthermore, the product was developed in line with specifications derived from observations and interviews. The analysis in this process includes: (a) Data/material needs analysis, (b) Functional needs analysis, (c) Software and hardware needs analysis, and (d) Specification needs analysis.

Design

In the design phase, the activity is to materialize the results of the conceptualization stage so that software developers can clearly understand the required needs. Activities in this modelling stage include creating User Experience (UX) designs using Unified Modeling Language (UML), including use case diagrams, sequence diagrams, and activity diagrams according to the features that need to be developed. Additionally, User Interface (UI) design, tailored to the product's needs, is also carried out. The outcomes of this phase include (a) UML, which includes use case diagrams, sequence diagrams, and activity diagrams. (b) User Interface design is depicted for each page.

Material Collecting

Material Collection is the stage where materials suitable for the project's needs are gathered. These materials include photos, animations, videos, and audio. This stage can be carried out simultaneously with the assembly stage or sequentially.

Assembly

In this stage, all created and collected elements are combined according to the design plan, including mechanisms, 3D objects, user interfaces, and programs. All these elements are managed and implemented through Unity software at this stage.

Testing

After the assembly stage is completed, the testing stage takes place. The testing method used is Alpha-Beta testing. This testing is carried out considering five of the eight aspects listed in ISO/IEC 25010 standards by Ben David's theory. These aspects include functional suitability, portability, performance efficiency, portability, and usability. The analysis is carried out on alpha testing to identify shortcomings in the developing application and to make improvements before testing it with a larger user base. Subsequently, beta testing is performed, involving direct user interaction to assess the application's usability aspects. Questionnaires are used in this testing, and museum visitors are used as user samples. Through questionnaires, usability aspects are tested. The purpose of this testing procedure is to produce an application with high feasibility.

Distribution

This stage is the final stage in product creation, where the product is distributed to users after passing feasibility testing. After completing the testing stage, an evaluation is conducted, and if errors are found in running the application, they need to be corrected. The result of this research is the Museum AR application. The application is distributed directly to the North Sulawesi Provincial State Museum. The

distribution process is conducted to deliver the product to users, aiming to achieve the research's objectives and targets.

Research Instruments

Research instruments are the tools selected or used to collect data systematically and facilitate the implementation of such activities. In this research, two types of instruments are employed by the data collection techniques employed, namely observation and questionnaires. (1) Quality Testing Instrument (2) Functional Suitability Testing Instrument (3) Performance Efficiency Testing Instrument (4) Portability Testing Instrument (5) Usability Testing Instrument

Data Analysis Techniques

In this research, a data analysis technique involving both qualitative and quantitative approaches is utilized. A qualitative approach is employed when analyzing observation data related to portability and performance efficiency aspects. The qualitative data analysis process in this research follows the stages described by Matthew B. Miles and Michael Huberman, namely data reduction, data presentation, and concluding the data processing results [19].

In analyzing the test data regarding functional suitability, usability, media feasibility, and content, a quantitative data analysis technique is employed. The scores obtained from the testing are calculated in the form of percentages using the following percentage calculation formula:

$$Percentage\ Score\ (\%) = \frac{Score\ Obtained}{Expected\ Score} x100\% \quad \text{..... (1)}$$

After obtaining the percentage results, the data is further converted into predicate statements. This conversion is carried out by referring to the score interpretation criteria listed in Table 1 to describe the condition or quality of the tested data [19].

Table 1. Percentage Likert Conversion Scale

No.	Percentage	Interpretation
1.	0% - 20%	Very Unsatisfactory
2.	21% - 40%	Unsatisfactory
3.	41% - 60%	Fair
4.	61% - 80%	Satisfactory
5.	81% - 100%	Excellent

RESULT AND DISCUSSION

Concept

Before commencing the conceptualization phase, the researcher interviewed the head of UPTD Taman Budaya and Museum, Department of Culture and Tourism of North Sulawesi Province. This interview aimed to gain an understanding of an effective application development concept to address the issues faced by the North Sulawesi Provincial State Museum, especially in introducing ethnographic collections. The following communication outcomes served as the basis for the conceptualization phase: (a) Some museum visitors do not fully comprehend the explanations provided for the ethnographic collections at the North Sulawesi Provincial State Museum due to the lack of detail in those explanations. (b) The process of introducing museum collections, particularly ethnographic collections at the North Sulawesi Provincial State Museum, still relies on conventional methods. (c) To date, there has been no utilization of technology or media to introduce ethnographic collections at the North Sulawesi Provincial State Museum. (d) The introduction of ethnographic collection media at the North Sulawesi Provincial State Museum needs to adopt a modern technological approach. (e) The use of interactive media is required to introduce ethnographic collections at the North Sulawesi Provincial State Museum to

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enhance visitor interest and facilitate their understanding and learning of the collections more effectively.

The conclusion drawn from this communication is that information about the ethnographic collections at the North Sulawesi Provincial State Museum is insufficient. The available explanations regarding the museum's ethnographic collections are inadequate, leading visitors to not fully grasp detailed explanations about the collections. To address this issue, the use of assistive media employing modern technology is necessary to introduce ethnographic collections at the North Sulawesi Provincial State Museum. This approach is expected to overcome the weaknesses of the conventional methods currently employed by the museum.

Based on the results of the communication and understanding of the issues faced, the developer collaborated with Mr. Drs. Ferdy Tamarindang, the museum's leader, to create precise product specifications. The resulting product specifications include: (a) The developed product is an Augmented Reality application designed to introduce the ethnographic collections at the North Sulawesi Provincial State Museum. (b) The developed medium must be capable of presenting clear and detailed information about each ethnographic collection at the North Sulawesi Provincial State Museum. (c) High-quality and easily understandable audio-visual content must be included in the media development. (d) The developed medium should provide a realistic and captivating depiction of the ethnographic collections at the North Sulawesi Provincial State Museum. (e) The medium to be built will be based on Android. (f) To achieve all the above goals, the developed medium will utilize Augmented Reality technology with a marker-based tracking approach.

Design

The UX (User Experience) and UI (User Interface) design processes are carried out during this stage. A use case diagram is a diagram that illustrates actors, use cases, and relationships within the system. Each use case represents interactions between an actor (user or external entity) and the system [19].

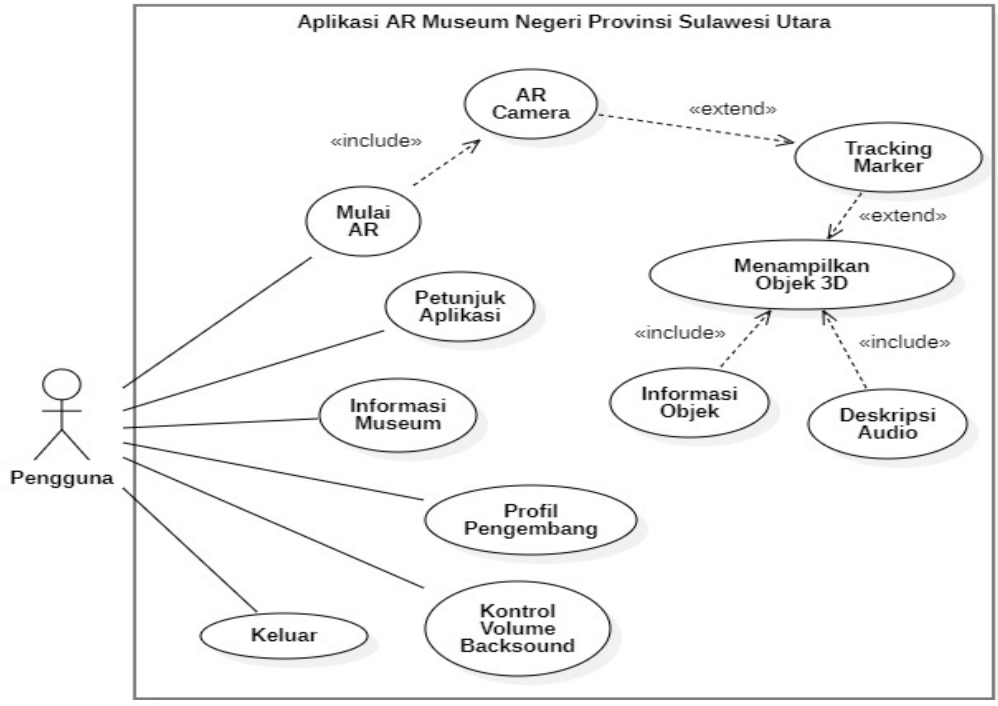

Figure 2. Use Case Diagram of ARMuseum Application

In UML modelling, an activity diagram can be used to depict in detail the operational and business workflow of a component of a system in a step-by-step format. The activity diagram for ARMuseum can be found in Figure 3.

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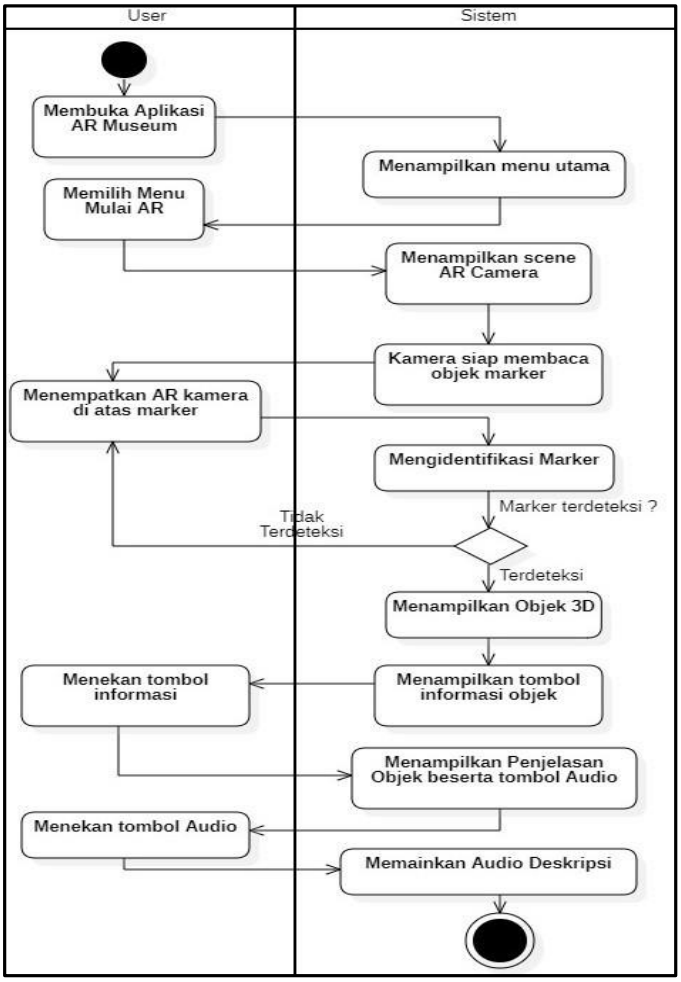


Figure 3. Activity Diagram of ARMuseum Application

A Sequence Diagram is a two-dimensional graphical representation that depicts objects along the horizontal dimension and lifelines along the vertical dimension. This diagram, as seen in Figure 4, is used to illustrate interactions among objects through the exchange of data in the correct chronological order.

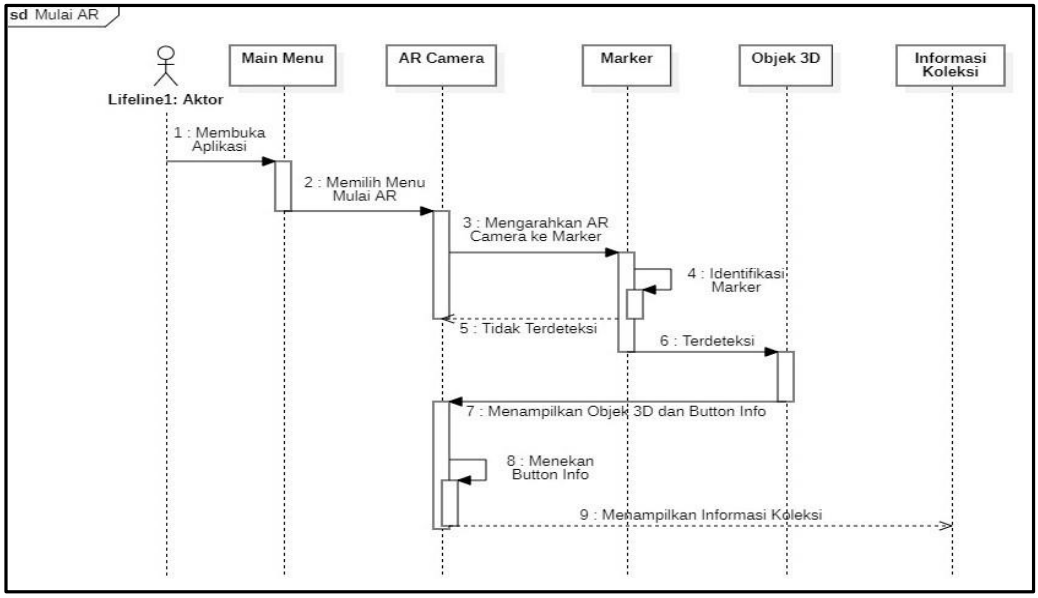
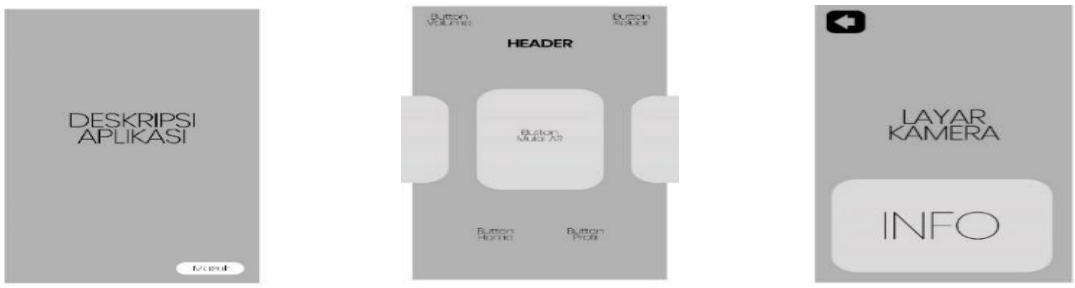


Figure 4. Sequence Diagram of ARMuseum Application

Wireframes are used in the user interface design. A wireframe is a basic framework or layout used to organize elements within an application. Wireframing is typically done as an initial step before the actual product is developed. Wireframes consist of elements such as text, images, layouts, and others that are interrelated in the application interface design [15].



(a) (b) (c)

Figure 5. (a) Application Description Menu, (b) Main Menu Scene. (c) AR Camera Menu

In Figure 5 (a), there is the Application Description Menu. This scene serves as the initial display before entering the main menu scene and contains a brief explanation of the developed application. Figure 5 (b) shows the Main Menu Scene. This scene contains buttons to navigate to other scenes. Furthermore, Figure 5 (c) illustrates the AR Camera Menu, which is a scene that utilizes the camera to display 3D objects using the Marker Based Tracking method.

(a) (b) (c)

Figure 6. (a) Application Guide Menu, (b) Museum Information, (c) User Info Scenes

In Figure 6, we have the Application Guide Menu, Museum Information, and User Info Scenes. Each of these scenes serves its purpose: Figure 6 (a) is dedicated to displaying instructions on how to use AR Museum, Figure 6 (b) provides information about the museum, and Figure 6 (c) presents the developer's profile.

Material Collecting

The material collection phase involves gathering all the necessary elements for application development, such as audio, 3D objects, and ethnographic collection materials. The required 3D objects and materials for application development can be created using specialized software that allows material processing: (a) Audio, the audio used in this application, consists of background audio obtained from YouTube and audio descriptions of collections created using text-to-voice technology. (b) Material and 3D Collection Objects, the materials and collections present in this application consist of 11 collections, namely: (1) Tabung Bambu, (2) Gilingan Batu, (3) Bika, (4) Loto, (5) Tolu, (6) Tolu Nelayan, (7) Wadah Batok Kelapa, (8) Igi-igi, (9) Pajeko, (10) Waruga, (11) Balongsong.

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Assembly

There are several steps of resource preparation for a development project, including (1) Resource Preparation (Hardware and Software). At this stage, resource preparation is carried out according to the hardware and software requirements. The following hardware is needed: A laptop or PC with a webcam and a smartphone camera. The required software includes Unity 3D, Vuforia SDK, Visual Studio, Blender, and Photoshop CC 2019. Once all the software has been prepared, the next step is the installation process. (2) Software Installation. In this stage, the prepared software is installed for readiness. In this context, out of the five required software, the developer only needs to install Blender because the other software is already installed. (3) Design and Marker Database Creation. The developer.vuforia.com website and Adobe Photoshop application are used to create marker designs and marker databases. (4) 3D Object Creation Process: In this stage, the process of converting 2D images into 3D models is performed using Meshroom and Blender applications.

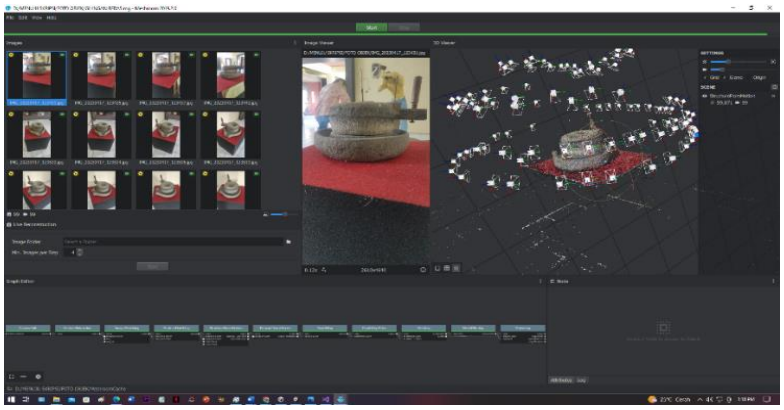

Figure 7. In Meshroom, 2D objects (Images) are transformed into 3D using Meshroom software.

After converting 2D objects into 3D models using Meshroom, the next stage is refining the model using Blender software. In this process, Blender is used for adjustments and improvements to the 3D model.

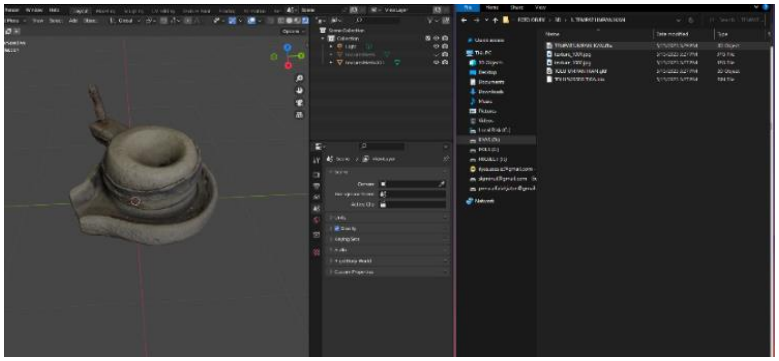

Figure 8. Finishing the ethnographic collection in Blender.

Implementation

The process of creating the main menu scene begins with arranging the layout. The previously designed layout is loaded into the "MainMenu" asset folder. Afterwards, the application's design is created using image objects as the background and button objects placed within the canvas. Additionally, the main camera is configured and adjusted to ensure that the screen resolution and aspect ratio are displayed correctly. An example of the main menu scene can be seen in Figure 9.

Figure 9. Creation of the Main Menu Scene

Creation of the instruction and museum information scenes. Overall, the process of creating scenes for user instructions and museum information follows similar steps to creating scenes for the main menu.

Figure 10. Creation of the Instruction Scene

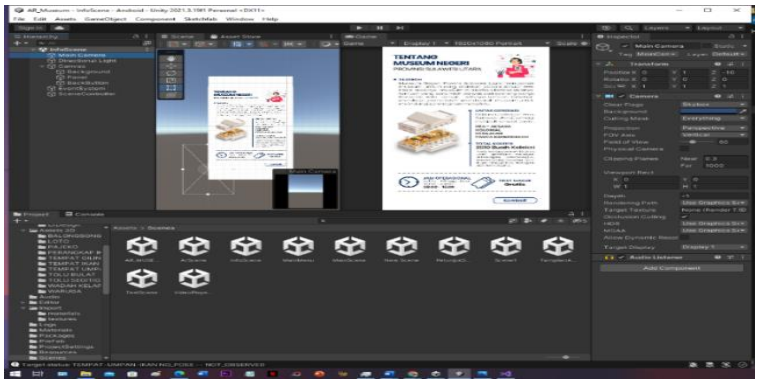

Figure 11. Creation of the Museum Info Scene

The Creation of the Augmented Reality (AR) Camera Scene for the Ethnographic Museum Collection. In contrast to how the main menu, instructions, and information scenes are created, in the AR scene, the main camera is not utilized. Its function is replaced by the AR camera, which has various camera functions for detecting marker images. In this application, the researcher employs marker-based tracking, using QR Codes as markers. Figure 12 shows the results of the AR Camera scene.

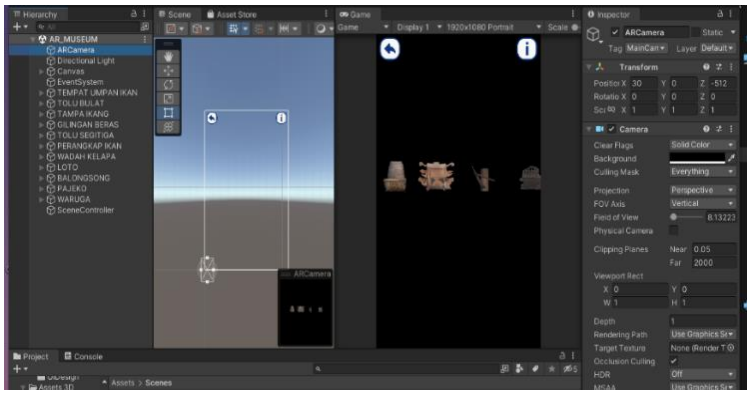

Figure 12. The Creation of the AR Start Scene

The final step in developing this application is to build the ARMuseum app for the Android platform for direct testing. The built application comes in the form of an APK file. To initiate the build process, the initial step is to configure settings through the Build Setting menu. Once the configuration is complete, the next step is to press the "Build" button to start the application-building process. After the build process is finished, the "ARMuseum" app is ready for testing. The main menu page displays the title of the application, "AR Museum Negeri Provinsi Sulawesi Utara." There are four buttons on this page: "Start AR," "Information," "Instructions," and "Profile." The "Start AR" button is used to begin the museum collection recognition. The "Instructions" button opens a page with instructions for using the application. The "Information" button opens a page with a brief profile of the Museum Negeri Provinsi Sulawesi Utara. The "Profile" button displays the developer's profile. There is also a "Power" button to exit the application. You can view the appearance of the main menu page in Figure 13.

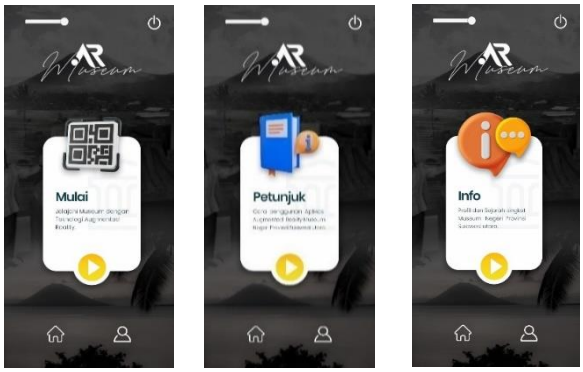

Figure 13. Main Menu Page

Start AR Menu Page. When users enter the "Start AR" page, the camera will be activated automatically. When users point the camera at the collection marker, a 3D object of that collection will appear on the screen. Additionally, there are information and back buttons. You can view the "Start AR" page layout in the provided Figure 14.

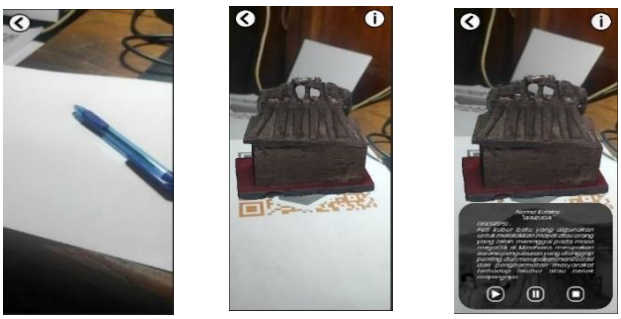

Figure 14. The Display of the Start AR Menu

The Museum Information, Application Instructions, and Developer Profile Menu Pages. In these three menus, each has a different scene. In the information menu, there is a description or profile about the North Sulawesi Provincial Museum. This information includes details about the museum, such as its history, the collections it possesses, and other additional information.

On the instruction menu page, there is information and guidance on how to use the application. Furthermore, on the profile page, it contains information and a profile of the developer. In this scene, there is only one button function, which is the home button. You can view the appearance of these menus in Figure 15.

Figure 15. Display of the main menu for museum information and application instructions

Testing

Results of Media Testing. In this testing phase, the researcher involved two lecturers who were experts in software engineering and multimedia. Media testing was conducted using a questionnaire that covered various related aspects.

Table 2. Results of Software Engineering Media Test

No	Indicator	Score results Expert		Amount	Score Max
		1	2		
1	Effectiveness	2	2	4	4
2	Reliability	2	2	4	4
3	Convenience	2	2	4	4
4	Usability	2	2	4	4
5	Compatibility	1	1	2	2
6	Technical quality	3	3	6	6
Total				**24**	**24**

Table 3. Multimedia Content Test Results

No	Indicator	Score results Expert		Amount	Score Max
		1	2		
1	*Audio*	3	3	6	6
2	Visual	3	3	6	6
3	Navigation	2	2	4	4
4	Communicative	2	2	4	4
5	Creativity	1	1	2	2
6	Picture	3	3	6	6
7	Button	2	2	4	4
Total				**32**	**32**

In material testing, the main focus was to evaluate the suitability of the descriptions of the ethnographic collection in the museum with the data available at the Museum of North Sulawesi Province. Material validation was carried out collaboratively involving three employees from the Museum of North Sulawesi Province, namely Mr. Drs. Ferdy Tamarindang, Mr. Roby Kolibu, and Mrs.

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Silvana Darsono, S.E. The results of material validation, conducted based on the questionnaire instrument, have been presented in Table 4.

Table 4. Material Testing Results

No	Collection	Expert			Amount	Score Max
		1	2	3		
1	Tabung Bambu	2	2	2	6	6
2	Gilingan Batu	2	2	2	6	6
3	Bika	2	2	2	6	6
4	Loto	2	2	2	6	6
5	Tolu	2	2	2	6	6
6	Tolu Nelayan	2	2	2	6	6
7	Wadah Batok Kelapa	2	2	2	6	6
8	Igi-igi	2	2	2	6	6
9	Balongsong	2	2	2	6	6
10	Waruga	2	2	2	6	6
11	Pajeko	2	2	2	6	6
Total		**22**	**22**	**22**	**66**	**66**

The results of the functional testing of the application to ensure that the functions in the ARMuseum application run perfectly and meet expectations have been presented in Table 5. This testing was conducted by the developer using test cases as instruments. The Guttman scale was employed in the measurement with characteristics of "YES or NO" and "SUCCESS or FAILURE" to obtain precise and clear answers, following the method mentioned by Sugiyono, 2011 [20] [21].

Table 5. Functional Suitability Testing Results

No	Feature	Obtained Score	Amount	Score Max
1	Main page	1	1	1
2	AR camera page	1	1	1
3	Displays 3D collections	1	1	1
4	Displays collection information	1	1	1
5	Play audio description	1	1	1
6	Museum info page	1	1	1
7	Application instructions page	1	1	1
8	Return	1	1	1
9	Exit the application	1	1	1
Total			**9**	**9**

Performance Efficiency Testing aims to evaluate the application's performance in two aspects, namely, lighting intensity and the distance between the device and the marker. The results of the Performance Efficiency testing for the Augmented Reality Museum application have been presented in Table 6.

Table 6. Performance Efficiency Testing Results (Distance)

No	Distance (cm)	Results	Info.
1	30		Detected

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No	Distance (cm)	Results	Info.
2	100		Detected
3	200		Detected

Table 7. Light Intensity Testing Results

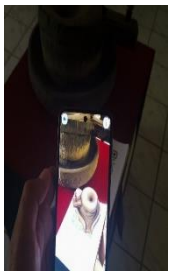
No	Light intensity (lux)	Results	Info.
1			Detected
2			Detected
3			Detected
4			Detected

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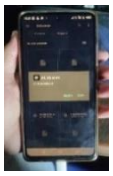
Table 8. Overall Performance Testing Results

No	Aspect	Score	Score Max
1	Marker distance	3	3
2	Light intensity	4	4
Total		**7**	**7**

Two aspects of portability testing are being tested, namely adaptability and installability. The adaptability and installability testing involves the process of trying to install, use, and uninstall the application on various versions of Android to evaluate the application's ability to adapt and be installed on different platforms.

Table 9. Results of Adaptability and Installability Testing on Different Android Versions

No	Android Version	Install	Running	Uninstall
1	OS Android 10 MIUI 11 (Redmi Note 9 Pro)			
2	OS Android 9 MIUI 11 (Redmi 7)			
3	OS Android 11 (Infinix Note 10 Pro)			

Based on the data in Table 9, it can be concluded that the ARMuseum software was successfully installed, used, and uninstalled on three different versions of Android. This indicates that the application has good adaptability and installability, as it functions effectively on various tested Android versions.

Table 10. Scores of Adaptability and Installability Test Results

No	Android Version	Install	Running	Uninstall	Amount	Score max
1	OS Android 10 MIUI 11 (Redmi Note 9 Pro)	1	1	1	3	3
2	OS Android 9 MIUI 11 (Redmi 7)	1	1	1	3	3
3	OS Android 11 (Infinix Note 10 Pro)	1	1	1	3	3
Total					**9**	**9**

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Table 11. Adaptability and Installability Test Results

No	Android Version	Install	Running	Uninstall
1	1080 x 2400 *pixels*			
2	720 x 1520 *pixels*			
3	1080 x 2460 *pixels*			

Based on the information provided in Table 11, it can be observed that the ARMuseum application was successfully installed, run, and uninstalled on three commonly used screen resolution versions. Table 12 presents the test score results indicating the quality and performance of the application in dealing with screen resolution variances.

Table 12. Data Results of Adaptability and Instability Testing on Different Screen Types

No	Screen Types	Install	Running	Uninstall	Amount	Score max
1	1080 x 2400 pixels	1	1	1	3	3
2	720 x 1520 pixels	1	1	1	3	3
3	1080 x 2460 pixels	1	1	1	3	3
Total					**9**	**9**

The application was tested by directly engaging museum visitors as users of the ARMuseum application. A total of 20 respondents were selected as samples for this testing. Questionnaires were employed in this testing method. The usability test results, including data descriptions, can be found in Table 13.

Distribution

This stage represents the implementation phase of the developed application. After undergoing testing, the application will be distributed to the Museum Negeri Provinsi Sulawesi Utara using a .apk file format, which is the extension used for applications on smartphones with the Android operating system.

Analysis of Media and Content Testing Results

The formula used to calculate the data analysis from the media testing results in the ARMuseum application is as follows :

$$Eligibility\ Percentage\ (\%) = \frac{24+32}{24+32} x100\% = \frac{56}{56} x100\% = 100\%$$

Based on the calculations, it can be concluded that the media in the ARMuseum application falls under the "excellent" category. This indicates that the media created, both in terms of information and multimedia content, has met the criteria for excellence.

$$Eligibility\ Percentage\ (\%) = \frac{66}{66} x100\% = 100\%$$

This calculation leads to the conclusion that the material in the ARMuseum application falls under the "excellent" category. This indicates that the descriptions of the museum's ethnographic collection in the application have been deemed valid because they are consistent with the data obtained from the museum.

Table 13. Usability Testing Results

No.	Question Number													Total	Max score
Respondents	1	2	3	4	5	6	7	8	9	10	11	12	13		
1	4	4	5	5	5	5	4	4	5	5	5	4	5	60	65
2	5	5	5	4	4	5	4	5	5	4	5	5	5	61	65
3	4	5	5	5	5	5	5	5	5	5	5	5	4	63	65
4	5	4	5	5	5	4	5	5	4	5	5	5	5	62	65
5	4	5	5	5	5	5	5	5	5	5	4	5	4	62	65
6	4	5	5	5	5	4	5	5	5	5	5	5	5	63	65
7	5	5	4	5	5	5	4	5	4	5	5	5	5	62	65
8	5	4	5	5	5	5	5	4	5	5	4	5	5	62	65
9	4	5	5	5	5	5	4	5	5	5	5	5	5	63	65
10	5	5	5	4	5	5	5	4	5	5	4	5	5	62	65
11	4	4	5	5	5	5	5	5	5	5	5	5	5	63	65
12	5	5	5	5	5	4	5	5	4	5	4	5	5	62	65
13	5	5	4	5	5	5	4	5	4	5	5	4	4	60	65
14	4	4	5	5	5	4	5	5	5	5	5	4	5	61	65
15	5	5	4	5	5	4	5	4	5	5	4	5	5	61	65
16	4	5	4	5	5	4	5	4	5	5	4	5	5	63	65
17	5	4	5	5	5	5	5	5	4	5	5	4	5	62	65
18	5	5	5	4	5	4	5	4	5	5	5	5	4	61	65
19	5	4	5	5	5	5	5	5	4	5	5	5	5	63	65
20	5	5	4	5	5	5	4	5	5	5	5	4	5	62	65
TOTAL														**1238**	**1300**

Analysis of Functional Suitability Results

$$Eligibility\ Percentage\ (\%) = \frac{9}{9} x100\% = 100\%$$

Based on the testing conducted by the developer, the ARMuseum application has a functional suitability level of 100%. Therefore, based on the percentage calculation of the application's quality in terms of functionality, the obtained rating is "Excellent".

Analysis of Performance Efficiency Testing Results

$$Eligibility\ Percentage\ (\%) = \frac{7}{7} x100\% = 100\%$$

From these results, it can be concluded that the ARMuseum application successfully operated well in two aspects, which are detecting objects at a marker-to-camera distance exceeding 1.5 meters (2

meters) and consistently detecting objects at a light intensity of 37 lux (low light conditions), whereas the normal indoor light intensity is 125 lux. Overall, the performance testing of the ARMuseum application achieved a score of 100% and is categorized as “Excellent”.

Analysis of Portability Testing Results

$$Eligibility\ Percentage\ (\%) = \frac{9}{9} x100\% = 100\%$$

From the observations, it can be concluded that the ARMuseum application meets the standards of adaptability and installability across various Android versions. The application's compatibility level with the tested Android versions reaches 100%, indicating that the application functions well and can be successfully installed on every tested Android version. Therefore, the ARMuseum application can be categorized as “excellent” in terms of adaptability and installability across various Android versions.

Analysis of Portability Testing Results Adaptability and Installability on Different Operating Systems

$$Eligibility\ Percentage\ (\%) = \frac{9}{9} x100\% = 100\%$$

Based on the observations, it can be concluded that the ARMuseum application meets the standards of adaptability and installability across various versions of Android. The application's compatibility rate with the tested Android versions reached 100%, indicating that the application functions well and can be successfully installed on every tested Android version. Therefore, the ARMuseum application can be categorized as "excellent" in terms of adaptability and installability across different Android versions.

Adaptability and Installability on Different Screens

$$Eligibility\ Percentage\ (\%) = \frac{9}{9} x100\% = 100\%$$

Based on the observation results, it can be concluded that the ARMuseum application meets the standards of adaptability and installability on different screen sizes. In the testing process, the application successfully achieved a compatibility level of 100% or can be categorized as 'excellent.' This indicates that the application can adapt and install effectively on various screen sizes, allowing users to access the application optimally without any difficulties.

Analysis of Usability Testing Results

$$Eligibility\ Percentage\ (\%) = \frac{1238}{1300} x100\% = 95.23\%$$

Based on the observations, it can be concluded that the ARMuseum application meets usability standards with a percentage of 95.23% or can be categorized as "Excellent."

Discussion of Research Results

This research aimed to introduce the ethnographic collection present in the North Sulawesi Provincial State Museum. To achieve this goal, the application was developed using the MDLC method, which consists of several stages: the conceptual stage, design, material collection, assembly, testing, and distribution. (1) **Concept**: Before commencing the technical development of the application, the conceptual stage was initiated as the initial step. Interviews were conducted with the North Sulawesi

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Provincial State Museum to understand the preservation challenges related to ethnographic collections in the museum. In collaboration with Mr. Drs. Ferdy Tamarindang, the museum's leader, specifications for the product were determined, and a software requirements analysis was carried out. The product specifications obtained were then used as a basis for conducting the needs analysis. The needs analysis was divided into four parts: data needs analysis to determine the content to be included in the application, functional analysis to determine the required functions of the application, hardware, and software needs analysis to determine the necessary hardware and software, and specification analysis to establish the minimum application requirements. This stage is crucial to ensure that the developed application aligns with the established needs and requirements. (2) **Design**: The next stage is the design phase, where the User Interface (UI) and User Experience (UX) are created. UI design is represented in the form of wireframes, while UX is represented in the form of UML diagrams, including use case, activity, and sequence diagrams. (3) **Material Collecting**: After the design phase is completed, the next step for the developer is to gather materials that are appropriate for the tasks at hand. These materials include photographs of the ethnographic collection objects in the museum, descriptions and explanations about the collection, and audio. In this stage, material collection is carried out to ensure that the content to be included in the application aligns with the previously established needs and specifications. (4) **Assembly**: The models that have been designed are then implemented in the assembly phase. This phase involves several steps, such as preparing the necessary hardware and software, installing software, designing the layout, and coding the application. (5) **Testing**: Subsequently, the testing phase is conducted, focusing on various aspects, including media and content criteria. Four aspects are the main focus of testing: performance efficiency (application performance), functional suitability (functional compatibility), portability (adaptability to various platforms), and usability (user-friendliness).

Material testing prioritizes the validation of ethnographic collection descriptions used in the application against the data available in the North Sulawesi Provincial State Museum. The material validation involves three employees from the museum: Mr. Drs. Ferdy Tamarindang, the head of UPTD Taman Budaya and Museum at the Provincial Culture Office of North Sulawesi, Ms. Silvana Darsono, SE, a member of the museum section, and Mr. Roby Kolibu, a museum guide.

The material testing results indicate that the descriptions of the ethnographic collection used are in line with the museum's data. The coefficient of material testing results reaches 100%, signifying that the material in the ARMuseum application is of very high quality. Media testing is carried out to evaluate whether the ARMuseum application is suitable for introducing ethnographic collections. This testing involves two expert professors in the fields of multimedia and software engineering. Media testing resulted in a coefficient of 100%, indicating that the ARMuseum application falls into the category of excellent.

The developer conducted functional suitability testing using test cases based on the functionalities of the ARMuseum application. The results showed that the application can execute all functions with a suitability level of 100%. Therefore, the application is considered excellent in terms of functional suitability.

Portability testing was conducted through observations by the developer. Observations involved testing the ARMuseum application on various Android devices with different operating systems and screen sizes. The results of portability testing showed that the ARMuseum application can be installed, run, updated, and uninstalled on various devices. Therefore, the application is rated as excellent in terms of portability.

Performance efficiency testing was performed through observations conducted by the developer. Observations involved testing various aspects of the augmented reality application, including marker distance and light intensity. Based on the observations conducted, the augmented reality Museum can be detected from a maximum distance of 200 cm and a minimum distance of 30 cm, with a minimum light intensity of 14 lux. The AR application testing received a score of 100%, categorizing the application as good.

Usability testing involved direct users, including museum visitors, middle and high school students, and university students. Testing was conducted using the J.R. Lewis questionnaire. The results of the usability testing showed that the usability aspect of the application received a score of 95.23%, categorizing it as.

CONCLUSION

Based on the research findings and discussions, the following conclusions can be drawn. The ARMuseum application was developed using marker-based augmented reality technology and Unity 3D, following the MDLC method, which encompasses conceptualization, design, material gathering, assembly, testing, and distribution. The application includes features such as the ability to display 3D objects from the ethnographic collection by scanning markers and providing text and audio descriptions of the items.

The ARMuseum application was specifically designed to address the issue of visitor boredom due to unengaging information. By integrating interactive 3D objects and multimedia descriptions, the application aims to make the information more engaging and dynamic, potentially reducing visitor boredom and enhancing the overall museum experience. The application addresses the previously identified lack of interactive media. Utilizing augmented reality to display 3D objects and offer interactive descriptions enriches the content and provides a more immersive experience for visitors.

Testing, evaluation, and analysis results indicate that the ARMuseum application exhibits excellent quality. Media and material aspects received a perfect score of 100%, and quality aspects, including functional suitability, performance efficiency, portability, and usability, also achieved a score of 100%. Although usability testing scored slightly lower at 95.23%, it remains within the excellent category. Overall, the ARMuseum application effectively meets the research's objectives by addressing visitor boredom and enhancing interactive media. It provides a more engaging and immersive experience, aligning with the initial goals of improving the presentation of the ethnographic collection at the North Sulawesi Provincial State Museum.

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